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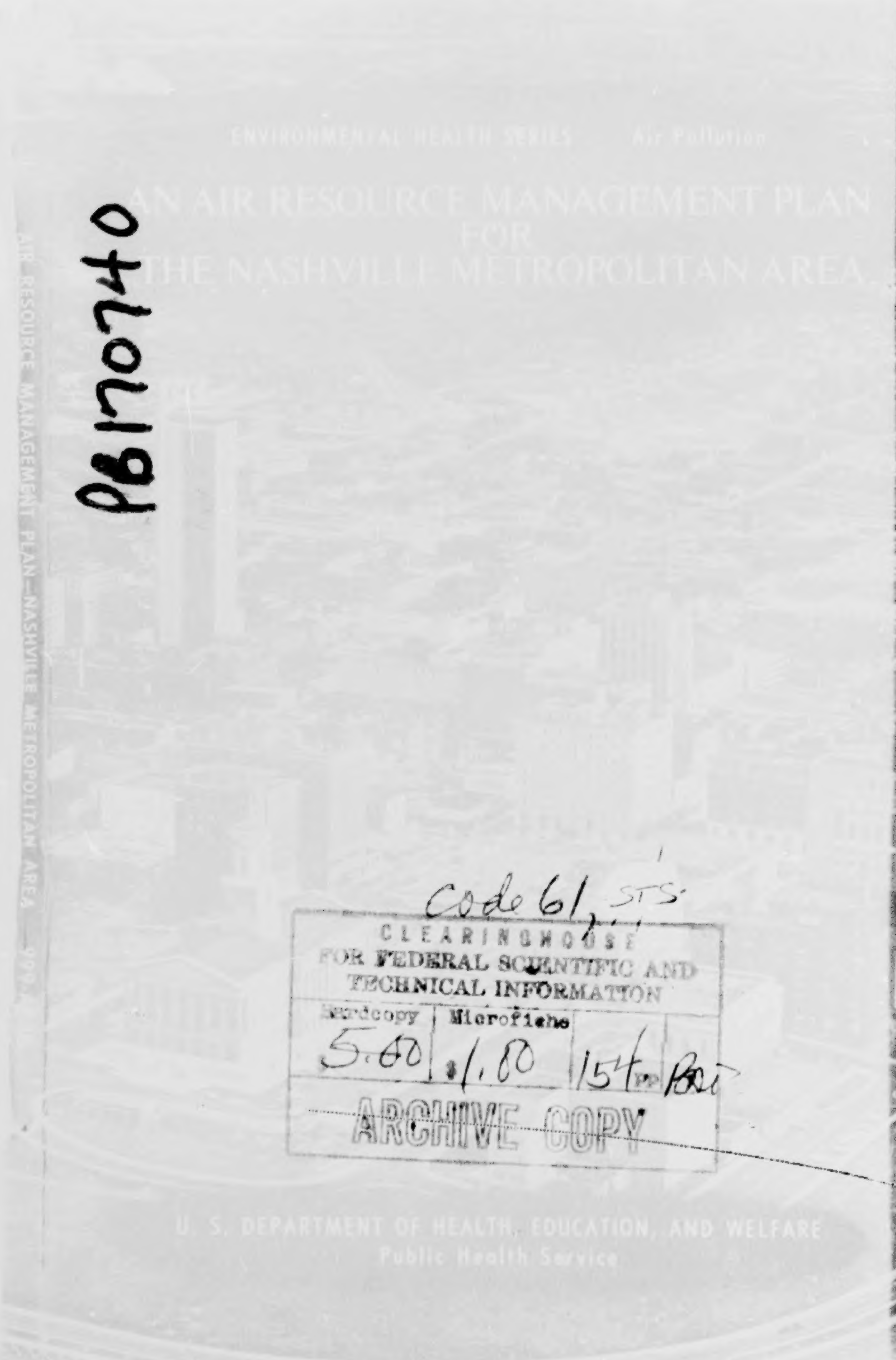
AN AIR RESOURCE MANAGEMENT PLAN FOR THE NASHVILLE METROPOLITAN AREA



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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

AN AIR RESOURCE MANAGEMENT PLAN
FOR
THE NASHVILLE METROPOLITAN AREA

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Division of Air Pollution

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Public Health Service Publication No. 999-AP-18

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3. Vanderbilt University.
4. Nashville - Davidson County Planning Commission.
5. Nashville Housing Authority.
6. State of Tennessee, Department of Public Health

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ABSTRACT

This report is based on the numerous technical and scientific papers resulting from a major study of air pollution and effects made in Nashville, Tennessee, by the Public Health Service, Vanderbilt University, and state and local agencies during 1958-59. These papers have been supplemented by field investigations to complete the background information needed for preparation of an air resource management program plan. The report summarizes a number of the technical and scientific papers and uses all of them to develop new concepts as well as unify new and old approaches to air pollution control in preparation of the air resource management program plan. Air quality goals and the means to reach those goals are suggested. Supporting data are provided and methodology adapted for relating air quality goals to control of emissions. Methods for predicting air pollutant levels by use of mathematical models are presented. Public opinion survey results and their implications for the air resource management program are given. The report has specific use for development of an air resource management program in Nashville and general use for program development and reference in many other places.

AN AIR RESOURCE MANAGEMENT PLAN FOR THE NASHVILLE METROPOLITAN AREA

SUMMARY

The primary purpose of this report is to assist the citizens and government of the Nashville Metropolitan Area in understanding the nature of their air pollution problem and in developing a course of action to improve air quality and assure clean air in the future by establishing an air resource management program. As an aid to fulfilling this purpose, air pollution is defined in considerable detail as it relates to the Nashville area. In some instances this definition has a unique application to the Nashville area because of the research conducted during the study. Ambient air quality goals are developed from the definition of air pollution, and suggested steps are indicated for the development of an air resource management program.

This report is based to a considerable extent on a major air pollution study carried on by the Public Health Service in cooperation with Vanderbilt University and state and local agencies. The study, begun in the fall of 1957, was carried on intensively in the latter part of 1958 and the first half of 1959. The resulting technical and scientific papers were the main sources of information for this report. These papers were supplemented in 1962 by an inventory of industrial air pollutant emissions.

Nashville has had a long history of smoke problems, with periods several years ago during which street and automobile lights were required until mid-morning even though the sky was clear outside the smoke area. These smoke problems, known to be associated with the use of high volatile content (soft) coal, were one of the reasons Nashville was selected for the study.

The Nashville Metropolitan Area (Davidson County), with a 1962 population of 415,340, is the capital city of Tennessee and the urban center for a large region. Its metropolitan area population has doubled in the past three decades. An even faster growth rate is predicted for the future because of industrial growth and a new network of expressways that will make distant areas more accessible. The Nashville area has taken a major step toward meeting the problems associated with this rapid expansion by changing to a metropolitan system of government.

A summary of the estimated principal air pollutant emissions indicates that coal burning contributes 85 percent of the sulfur oxides and 33 percent of the particulates. Gasoline consumption is a major source of nitrogen oxides and organic gases. (Carbon monoxide was not measured.) Refuse burning also accounts for a large part of the organic gases. Industries account for a considerable portion of the particulate matter emissions as well as other substances. Because of their nature and concentration, these industrial emissions are more important in certain geographical areas than the quantities in the emission inventory tend to indicate.

During the 1958-59 air pollution study, over 200,000 aerometric observations were made at 123 sampling stations. An analysis of these data indicated that 5,500 people live in areas where the insoluble portion of the dustfall is over 15 tons per square mile per month. The suspended particulate matter levels, as measured by the Hi-Vol filter, are over 150 micrograms per cubic meter in an area of 13.2 square miles in which 77,000 people live. About 7,200 people live in areas where suspended particulate matter is in excess of 200 micrograms per cubic meter. Over 88,000 people live in areas where soiling, as measured by the AISI strip filter paper sampler, is classified as "very heavy" (3.0-3.9 Cohs per 1,000 lineal feet). About 120,000 people live in areas where reactive sulfur compounds as measured by lead peroxide candles are in excess of 0.7 milligram sulfur trioxide per 100 square centimeters per day. The peak concentrations of sulfur dioxide, as measured by continuous recording equipment, show levels of 0.83 ppm for 2 hours; 1.8 ppm was the highest instantaneous recorded level. When compared with American cities in which the Continuous Air Monitoring Program of the Public Health Service has operated, these sulfur dioxide levels are next to the highest. Chemical analysis of suspended particulates collected in Nashville reveal the presence of considerable benzo(a)-pyrene. This polynuclear aromatic hydrocarbon is important because of its demonstrated ability to produce cancer in laboratory animals. In comparison with eight other cities studied, Nashville had the second highest level of benzo(a)pyrene. Total weights of particulate matter indicate that the annual geometric mean levels are about 25 percent higher than those found in other American cities of comparable size. It is concluded that Nashville has excessive air pollution.

Meteorological conditions for dispersion of air pollution in Nashville are poor in comparison with those in most areas of the country. Temperature inversions occur during 30 to 40 percent of the total hours. There were 31 stagnation cases of 4 days or more each from 1936 to 1956. The seasonal distribution of atmospheric stagnation periods and calms is: winter, 4 percent; spring, 5 percent; summer, 7 percent; and fall, 11 percent. Thus the fall season is most conducive to the buildup of pollutants. South and southeast winds predominate. Topographical influences on airflow cause concentration of air pollution in the central zone of the metropolitan area.

The relationships between air pollution and bronchial asthma, anthracosis, morbidity, and mortality were studied in Nashville. Bronchial asthma attack rates on days with the highest and lowest sulfur dioxide values were significantly different. The deposition of anthracotic pigment in lungs observed in 631 consecutive autopsies indicated an increase with age and was more severe in males than females and in Nashville residents than in out-of-city dwellers. Total morbidity (sickness) and cardiovascular morbidity in those people 55 years old and older were directly related to the air pollution soiling index and 24-hour sulfur dioxide levels. In housekeeping females, whose exposure to air pollution was largely limited to the home environment, direct correlations between total morbidity and air pollution were observed. Respiratory disease mortality (death) - with the exception of lung and bronchial cancer, bronchitis, and emphysema - was directly related to the degree of exposure to sulfation and soiling. Age-specific respiratory disease mortality rates up to 65 years of age were directly related to the degree of exposure to air pollution as measured by sulfation.

On days when the relative humidity is less than 70 percent, reduction in visibility is due, primarily, to particulate matter in the air. In observations made in Nashville from the Cordell Hull Building during periods of low humidity, visibility toward the west was almost always impaired.

As part of the morbidity survey, people in 3,032 dwelling units were interviewed to determine their awareness of air pollution. Extrapolation of these queries to the total 1961 Nashville population indicates that 50,000 of the 232,000 residents were bothered by air pollution and that 40,000 to 100,000 residents were bothered by different effects of air pollution, such as soiling, decreased visibility, odors, or damage to property.

In research done as part of the study new tools and concepts were developed. One of these was the use of mathematical atmospheric diffusion models as an aid to predicting air pollution levels. These models utilize computer programming to handle the complicated task of analyzing the many parameters of air pollution diffusion to obtain data for air-pollution-level prediction maps. The resulting method provides community planners and others with the means for predicting the effects of a proposed new land use on general air quality and help in developing an air resource plan that would be part of the comprehensive plan for the community. Air pollution prediction maps, which are part of this report, should be valuable to planners in the Nashville area.

A proposal is made for an air resource management program. This proposal is based on the emission levels, air pollution effects, and air quality levels found in Nashville. The proposed air resource management program consists of the following main parts and policies:

1. A continuous air quality monitoring program.

2. A current and continuing air pollutant emission inventory.

3. A full knowledge and use of conditions influencing the transport of air pollutants.

4. Air quality goals.
5. Community planning decisions based on air quality goals.
6. Air pollution control decisions and ordinances based on the information and scientific determinations made regarding air quality.

The following goals are suggested maximums: 200 micrograms per cubic meter of suspended particulates, as measured by the Hi-Vol sampler; 0.1 ppm sulfur dioxide, 24-hour average value; and a soiling index value of 4.5 Cohs per 1,000 lineal feet. These stated pollution levels are not to be exceeded over 1 percent of the time. The goal for dustfall is 10 tons per square mile per month (annual average), as indicated by the water insoluble portion of measured dustfall. Their justification and bases, as well as the methods by which they may be reached in terms of emission limits, are discussed.

Some specific air pollution control regulations are recommended, and some suggestions are made for organization of an air pollution control program. These are, in general, left to the individuals and agencies that will be using this report to bring about improvement in air quality levels and establishment of an air resource management program in Nashville.

RECOMMENDATIONS

To obtain air quality in keeping with the needs of the Nashville Metropolitan area, a comprehensive air resource management program must be developed. This program must provide the means for making equitable air resource management decisions and place in effective operation those measures decided upon. Directed toward both long- and short-term benefits, the program consists of the following principal parts:

1. Air Quality Monitoring — Air quality monitoring is essential for the protection of the public health and the operation of an air resource management program. A monitoring program that identifies short-time variations and long-term trends must be established for at least the following air pollutants:

   a. Sulfur dioxide.

   b. Settleable particulates.

   c. Suspended particulates.

   d. Oxidants.

2. Appraisal of Effects of Air Pollutants — The effects of air pollutants on human health, comfort, and welfare; the soiling and deterioration of materials; decreased visibility; and damage to vegetation attributable to air pollution should be monitored on a continuing basis and studies undertaken when needed.

3. Air Pollutant Emission Inventory — Knowledge of the types and quantities of materials emitted to the atmosphere is conducive to good air conservation practice and essential for the successfull operation of an air resource management program, a business, or a community. Those practices and mechanisms that will assure the gathering of this knowledge on a continuing basis should be established. The data should be made available to both private and public interests for use in improving existing air quality control practices and in controlling emissions when new products are being developed.

4. Air Quality Goals — Air quality goals must be established to limit pollutants to the following values:

a. 0.1 ppm sulfur dioxide (24-hour mean value), not to be exceeded on over 1 percent of the days during any 100-day period.

b. 200 micrograms per cubic meter of suspended particulate matter, not to be exceeded on more than 1 percent of the days during any 100-day period.

c. 4.5 Cohs, soiling index, not to be exceeded over 1 percent of the time during any 3 months. (Normally based on 2-hour samples collected on a continuing basis.)

d. 10 tons of dustfall per square mile per month (water insoluble portion only), not to be exceeded at any location on a yearly average basis. (Based on 30-day sampling periods.)

These goals apply to any inhabited area or where an effect of air pollution may be objectionable. Measurements of levels are based on sampling periods suitable for the pollutant and measuring method used.

5. Air Pollution Control Organization — An organization must be formed, financed, stuffed, and equipped to administer the air resource management program.

6. Planning and Zoning — Air quality must be considered in planning and zoning decisions and programs. Probable air quality levels that would result from certain planning decisions should be estimated. Mathematical atmospheric diffusion models should be used as an aid in making the estimates. Land use should be considered in terms of air use, and those uses and locations that will make the best use of the community air resource should be established.

7. Education and Information — A program of education and information must be initiated to inform the people of the Nashville Metropolitan Area of the air management program objectives and their roles in accomplishing those objectives.

8. Air Pollutant Emission Regulations — Ordinances or rules and regulations must be enacted and enforced to reach and maintain ambient air quality goals. The following is a summary of recommended requirements based on the emission inventory, measured air quality levels, and air quality goals:

   a. Prohibit all open burning.

   b. Require that refuse incinerators be of multiple-chamber design and limit particulate emissions to 0.3 grain per standard cubic foot from incinerators burning less than 200 pounds per hour and to 0.2 grain per standard cubic foot from larger units.

c. Prohibit emission of smoke as dark or darker than No. 1 on the Ringelmann chart and emission of other pollutants of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke as dark or darker than Ringelmann No. 1.

d. Eliminate use of coal in hand-fired units on a progressive basis over a period of 3 to 5 years.

e. Regulate emission of flyash from combustion of fuels on a graduated basis that requires better emission control on larger units than on smaller ones.

f. Limit emission of particulate matter from industrial processes on a graduated basis that requires better emission control on larger plants than on smaller ones.

g. Prohibit installation of any new coal-burning units having a heat input of less than 1,000,000 Btu per hour and, on a progressive basis, phase out existing coal burning units in this smaller size range wherever natural gas is available.

h. Limit the sulfur content of fuels to 2 percent by weight during the months of November through February.

i. Prohibit emission of odorous materials that cause a detectable odor (by normal observers) in the ambient air in areas used for residential, recreational, educational, and similar purposes; cause concentrations of odorous materials in ambient air that are detectable when diluted with four or more volumes of odor-free air in commercial areas; or cause concentrations of odorous materials in ambient air that are detectable when diluted with 12 or more volumes of odor-free air in industrial areas.

j. Require that wind-blown surface dust be controlled or prevented.

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INTRODUCTION

OBJECTIVE OF THE REPORT

The object of this report is to provide information that will help the citizens and government of the Nashville Metropolitan Area understand the nature and importance of their air pollution problems and to assist in developing a course of action for improvement of air quality in the immediate future and for management of air resources in years to come.

The information presented in this report, although among the most complete for any community in the world, does not describe all aspects of the air pollution situation in absolute terms. This deficiency cannot be avoided because the resources of basic data in the air pollution field are still limited, although they are expanding as the result of extensive, current research programs. In some matters conclusions must be based on the best judgments possible in view of the factual information available. To delay action until all decisions could be based on complete and exhaustive investigations would permit air pollution problems to become even more acute.

The general air pollution problem should be considered against the backdrop of community development and the series of problems that arise in that development. Each problem, in turn, calls for a solution, and upon being solved, allows for continued advancement to new areas of community welfare and individual well being. The field of environmental health with its governmental organization is only one part of that backdrop, which, viewed historically, has the following developmental sequence: Among the very first needs for successful urban living is a public water supply. A public water supply not only promotes the public health and welfare but also sparks residential and industrial development and commerce. The public water supply brings the need for sewers, which in turn leads to the need for sewage treatment. Garbage and rubbish collection and disposal with other vector control activities follow closely on the heels of sewer service. Food sanitation, plumbing regulations, and air pollution control follow closely or proceed concurrently with other activities. Housing improvement and urban renewal, while not clearly a part of a community development time sequence, are activities in which many phases of environmental health meet and thus provide an opportunity for a single solution to multiple problems. Eventually air resource management becomes of community concern and within the scope of community action.

This report is dedicated to assisting the citizens of the Nashville Metropolitan area to reach decisions concerning the future management of that most important and not unlimited resource - air.

SOURCES OF INFORMATION

This report has been prepared jointly by the City of Nashville, the Davidson County Health Department, and the United States Public Health Service. It stems from a decision made by these agencies on January 22, 1962 and recorded in a letter dated February 19, 1962, from the Public Health Service to Mayor Ben West. Although some additional studies were done, this report, for the most part, is an interpretation of appropriate parts of the information collected in the air pollution research studies done in Nashville from August 1958 through July 1959.[1] These research studies were done by the Public Health Service, which used its own staff and resources, and by contract with Vanderbilt University. The study was conducted in cooperation with the Tennessee Department of Public Health, Davidson County Health Department, Office of the Mayor of Nashville, Nashville Division of Smoke Regulation, and many other governmental and private agencies and individuals. Numerous scientific papers have resulted from these studies, and more are to be prepared. As more technical papers become available, they will be valuable for making further plans to improve and conserve the air resources of the Nashville area.

SURVEY AREA

The present report is concerned with all of Davidson County, although greatest attention is given to what was the City of Nashville and adjacent, highly urbanized areas (Figure 1). The research studies were done largely within an area about 9 miles in diameter, centered around the intersection of Ninth and McGavock Streets in the heart of Nashville. Aerometric data were collected in a network of 119 stations within this 9-mile-diameter area and at four control stations 3 miles beyond the station network (Figure 2).

SMOKE PROBLEMS - HISTORICAL REPORT

Nashville has had a long history of major smoke problems. A Weather Bureau report dated 1932, which discussed smoke observations made from the Stahlman Building, states, ". . . certain observations (were) made during several (four) winters beginning in 1927-28 . . . . Density of smoke was graded on the Ringelmann Scale." Data in the report indicate the average monthly smoke densities [2,3] for the four winters at the measurement times specified were as follows:

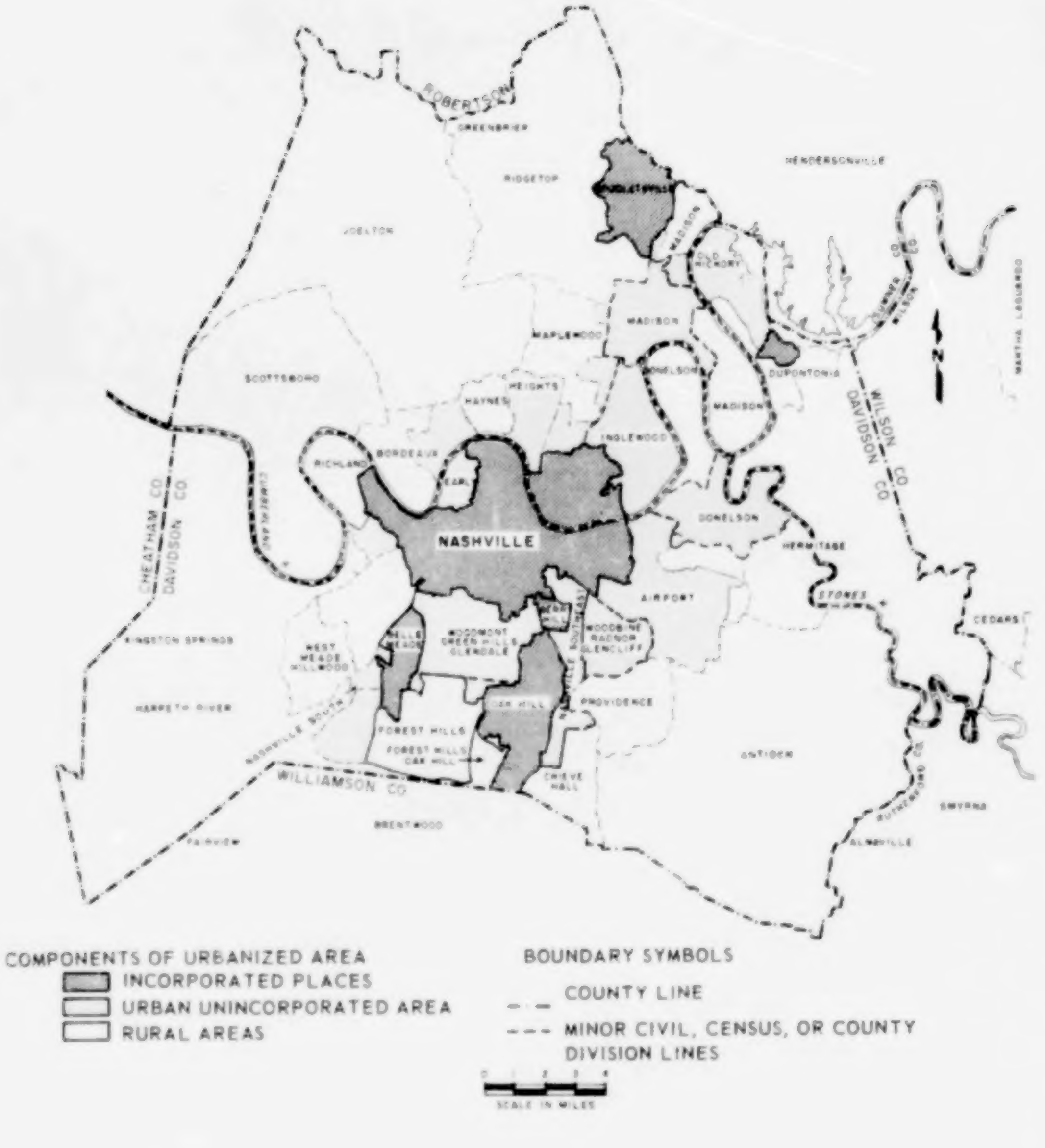
ROBERTSON
GREENBRIER
RIDGETOP
HENDERSONVILLE
JOELTON
MADISON
OLD HICKORY
SUMNER CO
WILSON
MARTHA LAGUARDO
MAPLEWOOD
MADISON
SCOTTSBORO
HEIGHTS
HAYNES
DONELSON
DUPONTONIA
MADISON
INGLEWOOD
WILSON CO
DAVIDSON CO
BORDEAUX
RICHLAND
EARL
CUMBERLAND
CHEATHAM CO
DAVIDSON CO
NASHVILLE
DONELSON
HERMITAGE
AIRPORT
STONES
CEDARS
KINGSTON SPRINGS
WEST MEADE HILLWOOD
BELLE MEADE
WOODMONT GREEN HILLS GLENDALE
BERRY HILL
NASHVILLE SOUTHEAST
WOODBINE RADNOR GLENCLIFF
HARPETH RIVER
OAK HILL
PROVIDENCE
NASHVILLE SOUTH
FOREST HILLS
FOREST HILLS OAK HILL
ANTIOCH
WILLIAMSON CO
CHIEVE HALL
RUTHERFORD CO
SMYRNA
BRENTWOOD
FAIRVIEW
ALMAVILLE
N
COMPONENTS OF URBANIZED AREA
INCORPORATED PLACES
URBAN UNINCORPORATED AREA
RURAL AREAS
BOUNDARY SYMBOLS
COUNTY LINE
MINOR CIVIL, CENSUS, OR COUNTY DIVISION LINES
0 1 2 3 4
SCALE IN MILES

Figure 1. Davidson County, Tennessee

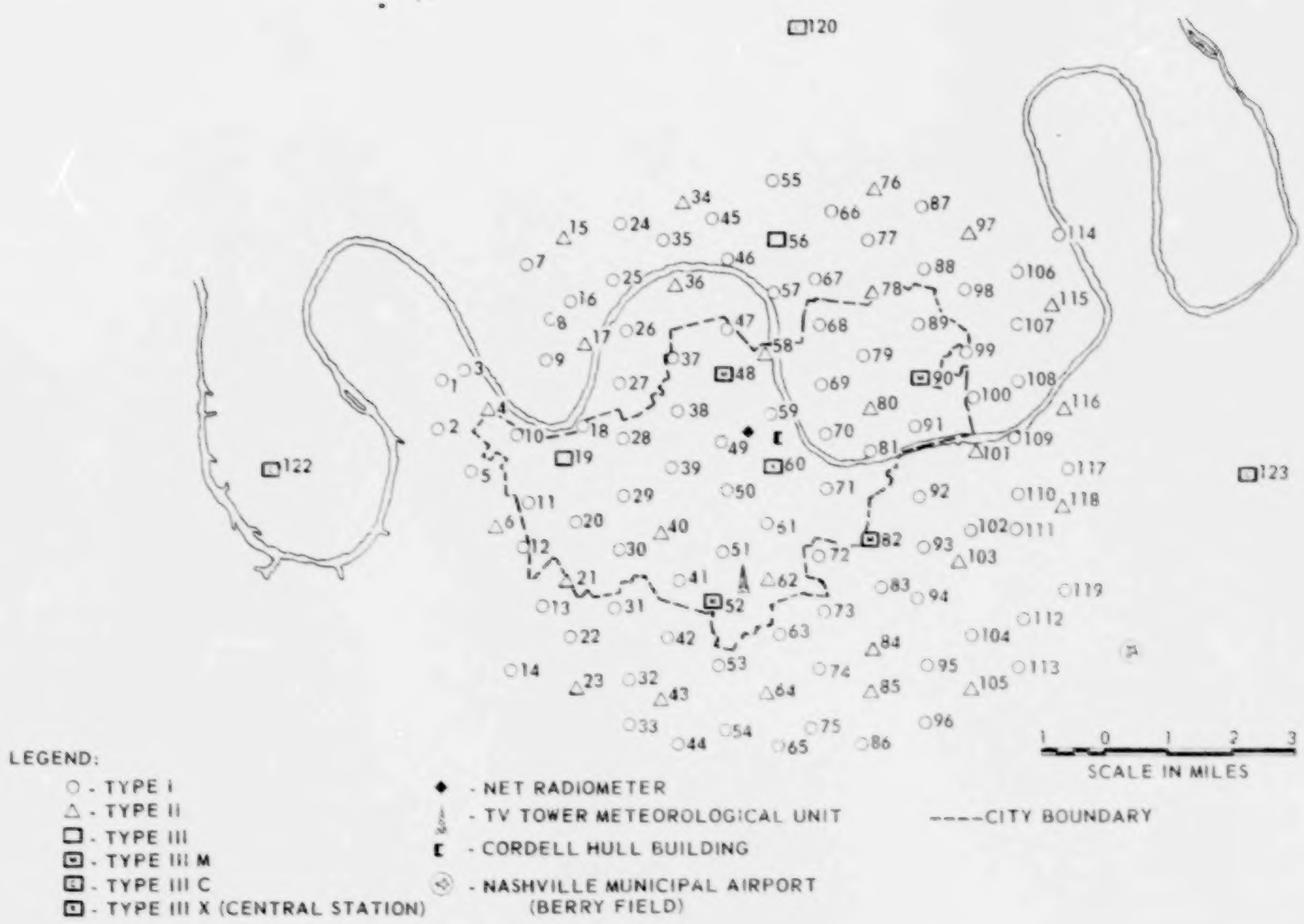
LEGEND:
○ - TYPE I
△ - TYPE II
□ - TYPE III
⊡ - TYPE III M
⊡ - TYPE III C
⊡ - TYPE III X (CENTRAL STATION)
◆ - NET RADIOMETER
- TV TOWER METEOROLOGICAL UNIT
- CORDELL HULL BUILDING
- NASHVILLE MUNICIPAL AIRPORT (BERRY FIELD)
----CITY BOUNDARY
1 0 1 2 3
SCALE IN MILES

Figure 2. Aerometric station network used in 1958-1959 Nashville community air pollution study.

Month	7 a.m.	9 a.m.	12 noon	4 p.m.
December	2.3	2.1	1.5	1.4
January	2.1	1.9	1.5	1.2
February	2.1	1.8	1.2	1.1
Winter	2.2	1.9	1.4	1.2

The detailed records show that there was some smoke nearly every day in the winter months, although there were several periods of 3 or 4 consecutive days when none was observed.

In 1935, Jones [4] reported: "Few cities in the United States have a greater smoke nuisance to contend with during the winter months than Nashville, Tennessee. It has been so dense on occasions that the visibility was reduced to zero, the sun's disc invisible from street level, and street and automobile lights kept burning until after 10:00 a.m., although at the same time just outside the smoke area the sky was brilliantly clear." In 1946 a U.S. Weather Bureau report [5] stated: "The Nashville smoke height is approximately 250 feet with a radius of approximately 4 miles. Formation of the smoke shroud over the city is directly due to meteorological conditions combined with local geographical features which go to make up a perfect union for stagnation of the lower atmosphere."

Although the smoke problem is not so severe now as it was 10 to 20 years ago, the 1958-1959 studies show that considerable further improvement should be made.

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COMMUNITY DEVELOPMENT TRENDS AFFECTING AIR POLLUTION

POPULATION

A review of the Nashville City and Davidson County Planning Commission's Population Report Number 4, of February 1960,[6] reveals that for many years prior to World War II, Nashville's growth pattern followed the major transportation lines that radiated out from the center of the city. Since World War II, the predominant pattern has been growth around the edges of the urban area and a decrease in population in the central part of the city. This changed pattern has been attributed largely to increasing use of automobile transportation, although the high air pollution levels in the central part of the city may well have been a contributing factor. The type of growth of the past few years will probably continue because of the new network of expressways that is now making areas distant from the city more accessible. As a result, the central part of the city may suffer still further decreases in population, although this trend is being countered by attractive high-rise apartment buildings, an auditorium, and other features that give the central business district a new character. The tenants and owners of these new buildings are not likely to tolerate air pollution, and the success of the whole redevelopment venture may be dependent upon reasonably clean air in the central area.

The exodus from the central city area has left large areas for industrial development. Industrial land is also being increased by flood control projects that will allow building on a greater part of the former river flood plain and by renewal projects that have demolished approximately 2,700 buildings, have some 1,700 more planned for demolition, and have hopes of eliminating practically all substandard housing in the city by 1972. Homes that formerly wafted coal smoke, ash, and sulfur dioxide into the community atmosphere are being replaced by new buildings heated with gas, electricity, or oil. This trend plus an aggressive program for industrial development may materially change the complexion of the air pollution problem in a very few years.

The population of Nashville increased steadily from 1900 to 1950, but decreased slightly from 1950 to 1960 (Table 1, Figure 3). The population of Davidson County has increased steadily since 1900. Most of the growth in total county population since 1930 has been in areas outside the City of Nashville. In March 1961 the City of Nashville annexed 42.5 square miles, bringing about 80,000 people into the city.

Table 1. POPULATION [a] OF DAVIDSON COUNTY, NASHVILLE, AND TENNESSEE SINCE 1900

Year	Davidson County			State of Tennessee
	Total	Outside city	Nashville	
1900	122,815	41,950	80,865	2,020,616
1910	149,478	39,114	110,364	2,184,789
1920	167,815	49,473	118,342	2,337,885
1930	222,854	68,988	153,866	2,616,556
1940	257,267	89,865	167,402	2,915,841
1950	321,758	147,451	174,307	3,291,718
1951	329,557	156,035	173,522	3,319,255
1952	337,355	164,619	172,736	3,346,792
1953	345,154	173,203	171,951	3,374,329
1954	352,952	181,787	171,165	3,401,866
1955	360,751	190,371	170,380	3,429,404
1956	368,549	198,955	169,594	3,456,941
1957	376,348	207,539	168,809	3,484,478
1958	384,146	216,123	168,023	3,512,015
1959	391,945	224,707	167,238	3,539,552
1960	399,743	228,869[b]	170,874[b]	3,567,089
1961	407,500	156,613[c]	250,887[c]	. . .
1962	415,340	. . .	. . .	. . .

[a] U. S. Census of Population and Chamber of Commerce estimates as of April 1, 1962, taken from Reference 28.

[b] Data reflect annexations to City of Nashville - 6.9 square miles included in 1960 Census.

[c] Data reflect 42.5 square miles added to city in March 1961.

Nashville and Davidson County have taken a bold step designed to meet the needs for improved community government by organizing a metropolitan system of government. The need for area-wide air pollution control was among the reasons for this governmental change. Air pollution does not respect political boundaries; therefore, prevention and control programs can be most successful when applied over entire air pollution basins or metropolitan areas.

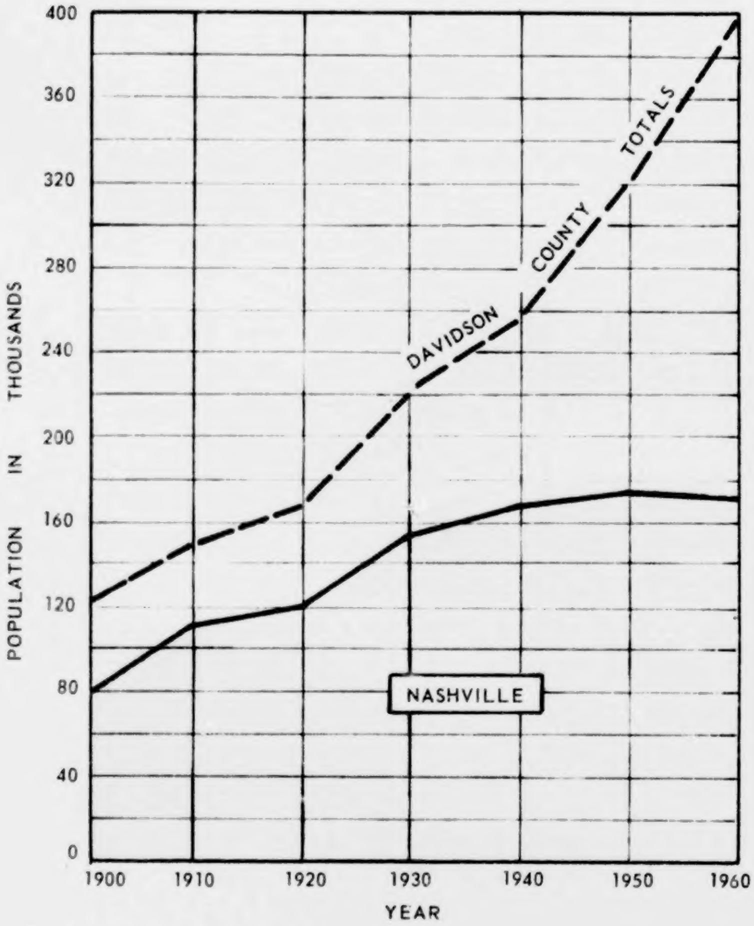

Figure 3. Population trends in Davidson County.

SPACE HEATING TRENDS AND ECONOMIC ANALYSIS

Since World War II the use of coal for space heating has declined in Nashville. This has been accompanied by a sixfold increase in the consumption of electricity during this period. The use of natural gas increased threefold from 1950 to 1960 (Figure 4). Since burning of coal was the source of approximately 85 percent of the sulfur dioxide and 33 percent of the particulates emitted to the atmosphere in 1958, the trend away from its use is of primary importance in improving air quality in Nashville. The following economic analysis will assist in evaluating the relative costs and other factors relating to use of various fuels.

The Nashville Urban Renewal Project and the Nashville Housing Authority in developing projects have analyzed the relative merits of different means of space heating. In a report obtained from a local architectural firm, gas was recommended on the basis of cost of the various fuels in large quantities (commercial rates) and consideration of constructions costs. [7]

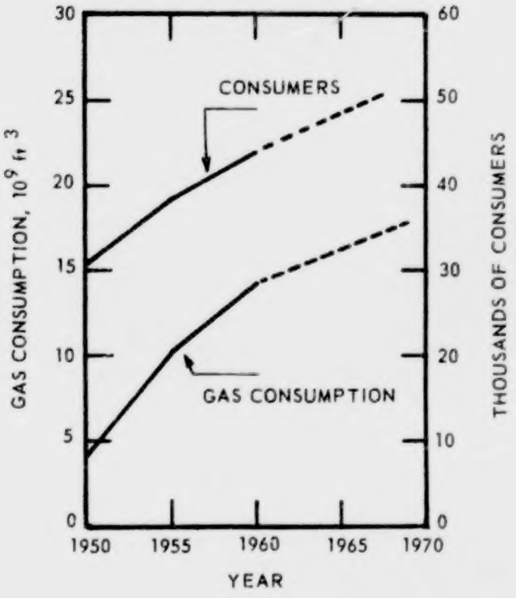

Figure 4. Natural gas consumption and consumers in Davidson County.

To a considerable extent in the cost analysis shown in Table 2 and other studies, gas and, in some cases, electricity were selected because of the greater construction costs associated with the use of coal. For example, a coal storage bin and higher cost chimney would partially offset the higher fuel cost of gas or electricity. Also, labor costs are reduced with gas or electric heating as compared to coal, since no labor is needed to feed fuel to the furnace, nor to remove ashes. Other advantages of gas and electric heat are easier regulation of the heating installation and improved cleanliness.

In a housing project fuel cost analysis report prepared in April 1962, coal was not even discussed. This would seem to indicate substantial acceptance of fuels other than coal for space heating.

Urban renewal and home improvement programs, under the present fuel price structure and with the policies currently in use, should have considerable impact on this part of the Nashville air pollution problem.

The 1960 Census reports 120,847 dwelling units in Davidson County; 55,623 of them were in the City of Nashville. For the county as a whole, 39,534 were heated with electricity, 39,919 with gas, and 28,879 with coal. Of those heated with coal, 17,828 were located within the city limits (Table 3).

The Nashville health effects survey questionnaire revealed that only 178 of 2,833, or 6 percent, of the homes surveyed used coal for cooking as compared to 995, or 33.6 percent, using coal for heating. This indicates that a large number of the homes presently using coal

Table 2. SPACE HEATING COST COMPARISON

Heat source	Gross cost, cents/therm	Efficiency of combustion unit[9], %	Net cost, cents/therm	Average annual space heating cost, dollars[d]
Coal				
Residential				
Hand-fired WK[a]	5.04	50 - 65	9.17	96
Hand-fired EK[b]	6.46		11.74	123
Stoker-fed WK[a]	5.04	50 - 70	7.76	81
Stoker-fed EK[b]	6.24		8.91	94
80-lb bags WK[c]	6.25	50 - 65	11.38	120
Commercial				
Hand-fired WK[a]	4.21	50 - 65	7.66	n.a.
Hand-fired EK[b]	6.45		11.74	
Stoker-fed WK[a]	4.21	50 - 70	6.48	n.a.
Stoker-fed EK[b]	5.94		9.15	
Natural gas				
Residential	9.8[8]	75 - 80	13.06	137
Commercial	7.8[8]	75 - 80	10.2	n.a.
Fuel oil	11.5	65 - 80	15.33	161
Electricity	21.5	100	21.5	226

[a] Western Kentucky coal in ton plus lots, delivered.

[b] Eastern Kentucky coal in ton plus lots , delivered.

[c] Western Kentucky coal.

[d] Average space heating cost for residence of 1200 square feet.

n.a. - Not applicable.

Table 3. DWELLING UNITS AND TYPE OF FUEL USED FOR SPACE HEATING, COOKING, AND HOT WATER HEATING[a] IN 1960

	Davidson County	Nashville	Urban balance	Rural
All housing units	120,847	55,623	52,939	14,285
Occupied units	114,635	50,990	50,742	12,903
Fuel used for space heating				
Natural gas	37,850	24,552	12,685	613
Oil	5,132	1,280	2,589	1,263
Coal	28,879	17,828	7,880	3,171
Electric	39,534	5,713	27,043	6,778
LP gas	2,069	1,134	470	465
Other	1,063	391	59	613
None	108	92	16	--
Fuel used for cooking				
Natural gas	19,929	16,679	3,084	166
Oil	623	519	62	42
Coal	4,332	3,835	420	77
Electric	85,607	27,702	46,059	11,846
LP gas	2,307	1,054	814	439
Other	895	419	143	333
None	942	782	160	--
Fuel used for water heating				
Natural gas	22,089	16,934	4,845	310
Oil	238	79	116	43
Coal	2,529	2,060	451	18
Electric	75,445	22,718	42,632	10,095
LP gas	1,365	1,093	211	61
Other	190	96	20	74
None	12,779	8,010	2,467	2,302

[a] Taken from Reference 8.

for space heating have another heat source on the premises and therefore could possibly discontinue use of coal for space heating. If the use of coal for domestic heating were reduced, the entire community would benefit through a decrease in air pollution, particularly in black smoke and sulfur dioxide.

Many people buy coal in small quantities because they do not have sufficient money available at one time for larger purchases. Heating costs are relatively high when this is done as indicated by the following. Consumers Price List Number 102 of the St. Bernard Coal Company indicates a price of $10.10 per ton at the yard for 7- by 3-inch chunk coal washed to remove dust. (The sulfur content of 3.0 percent is not changed materially by this kind of washing.) This coal has a heating value of 12,000 Btu per pound, or 240 therms per ton; its cost is equivalent to 4.21 cents per therm. This is lower than the coal costs used in the space heating cost summation (Table 2). The difference can be accounted for by delivery costs. If this same coal is purchased in 80-pound bags, it costs 60 cents per bag, or $15.00 per ton, bringing the cost to 6.25 cents per therm. On this basis, and in view of the relatively low efficiency of domestic, hand-fired coal-burning furnaces, the annual cost of heating an average-size residence would be about $120. The cost to heat the same residence with gas would be about $137 (Table 2). In view of the other advantages of gas heating previously mentioned, the benefits to be achieved seem well worth this small additional cost.

The Census of Housing [8] also indicates that in 1960 4,332 dwelling units used coal for cooking and 2,529 used coal for hot water heating (Table 3). Some of the dwellings using coal for hot water heating are apartment houses; the remainder are probably single-family units. Coal-fired cooking stoves and small coal-fired hot water heaters nearly always cause emission of excessive smoke and are an inconvenience out of keeping with modern living. They should be eliminated wherever feasible and as soon as possible. Gas- or oil-fired units or electrically operated devices are much preferred.

In conclusion, there are substantial improvements that could be made in space heating, cooking, and water heating equipment. These changes would hasten a general trend, which has long existed, and would provide cleaner air for the people of the Nashville area.

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SOURCES OF AIR POLLUTANTS

Air pollutants are emitted to the atmosphere from a wide variety of sources in any metropolitan area. They are among the undesirable by-products of urban living. Large quantities of contaminants are formed by burning coal; and lesser quantities, by burning oil or gas. Refuse-burning in incinerators, dumps, and open fires gives rise to important quantities of pollutants. Certain industrial, commercial, transportation, and agricultural activities release pollutants to the atmosphere. The purpose of this section is to indicate the relative magnitude of these various sources of pollution as well as the total quantities of various pollutants being discharged to the atmosphere in the Nashville area.

FUEL COMBUSTION IN STATIONARY SOURCES

The type of fuel used in a community establishes, to a considerable degree, the nature and quantity of pollutants discharged to the air. Fuels are burned for space and water heating, for cooking, for power generation, and for industrial process heating. (Use of fuel in mobile sources, such as automobiles, is considered later in this report section.)

In general, burning of coal results in more pollutant emissions than does burning of oil or gas. In hand-fired units, burning coal without causing excessive smoke emissions is very difficult. Coal with a low volatile content will, in general, produce less smoke than coal with a high volatile content. Use of mechanical stokers to feed either low or high volatile coal to a combustion unit reduces emission of smoke appreciably. Many types of mechanical stokers cause excessive emission of ash, and dust collecting equipment must be installed in the exhaust system of the furnace.

No matter how coal is burned, a high percentage of the sulfur in the coal finds its way into the atmosphere as sulfur dioxide. The same is true for other fuels; but since coal usually contains more sulfur than either oil or gas, it releases more sulfur dioxide than the other two fuels in doing the same heating job. At present, no economically attractive means is known for removing sulfur dioxide from stack gases although research in this field is very promising. Some coals to be used for certain purposes can be cleaned or washed in such a way that about 25 percent [9] of the sulfur is removed. This would, of course, reduce emissions of sulfur dioxide when the coal is burned.

Oil may be burned with practically no visible smoke emission; but if improper firing practices are used, if fuel unsuitable for a particular combustion device is used, or if equipment is defective, excessive smoke emissions may occur. Sulfur content of light fuel oils (Numbers 1 and 2) is generally low; heavier oils (Number 4, 5, and 6) may contain substantial amounts (Table 4). Nearly all of this sulfur is discharged to the atmosphere as sulfur dioxide when the oil is burned. Oil also contains some ash, which may be emitted to the atmosphere in burning fuel. The amount is very small, however, and only in extreme circumstances does it become a matter of community concern as an air pollutant.

Table 4. WEIGHT PERCENT SULFUR IN VARIOUS FUEL OILS DETERMINED BY BUREAU OF MINES IN 1961 [a]

Fuel oil grade	Eastern Region			Southern Region[b]			Central Region		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
1	0.007	0.069	0.17	0.01	0.068	0.21	0.005	0.107	0.48
2	0.04	0.228	0.65	0.04	0.249	0.72	0.071	0.299	0.81
4	0.18	0.84	2.12	0.27	c	1.92	0.27	0.90	2.12
5	0.28	1.17	2.50	0.28	1.77	3.10	0.57	1.52	3.5
6	0.53	1.34	3.40	0.34	1.58	3.36	0.42	1.47	4.0

[a] Taken from Reference 10.

[b] Tennessee is located in this region.

[c] No averages were computed because only two samples were used in this test.

Burning of natural gas results in very little emission of sulfur dioxide and practically no emission of smoke.

Burning of all fuels results in emission of oxides of nitrogen (mainly nitrogen dioxide and nitric oxide), the amount depending on the fuel burned, furnace design, and combustion conditions.

Broad general averages of the amount of several pollutants emitted in using coal, oil, and gas are shown in Table 5. The merits of each fuel, from an air pollution point of view, are readily discernible.

The Nashville Metropolitan Area, until recent years, depended primarily upon high volatile coal for heating. This practice resulted in a fall-winter chronic air pollution condition during the heating season. Since World War II, the local use of coal has declined and natural gas and electricity have become the principal energy sources. The consumption of electricity increased sixfold since World War II, and during the period 1950-1960 the use of natural gas increased threefold (Figure 4). In 1946, coal consumption in the Nashville area was

Table 5. EMISSION FACTORS FOR CONSUMPTION OF FUEL [a] BASED ON BROAD GENERAL AVERAGES

Pollutant	Pollutant emitted per 1,000 pounds fuel fired, lb					
	Coal [b]		Oil [c]		Gas [d]	
	Industrial	Residential and commercial	Industrial	Residential and commercial	Industrial	Residential and commercial
Total solids	22[e]	12	1	1.5	nil	nil
Inorganic gases						
Sulfur oxides (as SO_2)	63	63	9.8	9.8	0.028	0.028
Nitrogen oxides (as NO_2)	10	0.2	13	9	5	4
Organic gases						
Hydrocarbons	1	5	0.4	0.25	0.1	0.1
Aldehydes (as HCHO)	n.a.	n.a.	0.07	0.25	0.4	0.6

[a] Taken from References 12 and 13.

[b] Coal - sulfur 3.5 percent by weight.

[c] Oil - sulfur 0.5 percent by weight.

[d] Natural gas weighs 55 pounds per 1,000 cubic feet and contains 0.0014 percent sulfur by weight.

[e] Averaged "uncontrolled" emission factor.

n.a. - Data not available.

942,976 tons; by 1955 its usage had dropped to 428,244 tons. [3] The reason for this decline is partially explained by the extension of gas pipelines and improved competitive position of the prices of gas and electricity as compared to coal. Other advantages of gas and electricity are: elimination of fuel storage space requirements, no manual handling of fuel, less costly fuel burning equipment, no ash handling, availability of simple automatic control devices, and cleaner conditions in the building using the energy. Coupled with these advantages is an improvement in general community air quality.

A detailed inventory was made of emissions of sulfur dioxide in the Nashville area in 1958-59.[11] This inventory indicated that a total of about 463,200 tons of coal was used per year in the Nashville urbanized area (the study area shown in Figure 2). About one-third of this was used in residences, primarily for space heating. One-third was used in commercial and industrial establishments for space heating, water heating, and power generation, and the remaining one-third was used for industrial process heating. The bulk of the coals used in the Nashville area are from Western Kentucky fields. Varying from one mine to another (Table 6), these coals have a sulfur content of about 3.0 to 4.4 percent, an ash content of about 5.5 to 10.5 percent, and a volatile content of 39 to 44 percent.

The sulfur dioxide emission inventory of 1958-59 indicated that a total of 25,700,000 gallons of oil was used per year in the Nashville urbanized area (the study area shown on Figure 2). The distribution of fuel oil consumption in the 1958-59 inventory was as follows:

Commercial	10,700,000 gallons per year
Industrial	6,290,000 gallons per year
Residential	8,710,000 gallons per year

According to the local fuel oil distributors, the fuel oil used in the Nashville Metropolitan Area is light distillate oil of grades 1 and 2. A small percentage of grade 4 or a mixture of grades 2 and 4 is occasionally sold for local consumption. The residual oils, grades 5 and 6, in 1962 were not available in the area. The best estimates available of the sulfur contents of the several grades of fuel oil used in Nashville are given in Table 4. In preparing the emission estimates for this report, an average sulfur content of 0.5 percent was assumed, based on limited data on the amount of each grade of oil used and the sulfur content of each grade as indicated in Table 4.*

In February 1962 a questionnaire was sent to 529 establishments listed in the 1962 Directory of Nashville Manufacturers [15] to determine the nature and extent of emissions of air contaminants. Replies were received from 317 firms (60 percent). The types of energy sources used by these firms for space and process heating are given in Table 7.

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*In the detailed emission inventory prepared in 1958-59,[11] an average sulfur content of 2.1 percent was used. More recent information leads to the conclusion that 0.5 percent is a better estimate.

Table 6. ANALYSIS OF COAL DURING FISCAL YEAR 1958 [a]

Area, county, town, and mine	Moisture (as received), %	Dry coal analysis, %				Btu/lb (as received)
		Volatile matter	Fixed carbon	Ash	Sulfur	
WEST KENTUCKY						
Hopkins County						
Beulah						
Anber[b]	6.3	39.6	49.9	10.5	4.4	12,210
Meadows[b]	6.1	43.6	50.7	5.7	3.3	12,880
Nortonville:						
Blue Flame	6.7	40.7	49.5	9.8	4.1	13,040
Dowson Springs:						
Franklin[b]	5.4	43.3	51.2	5.5	3.4	13,780
Webster County						
Providence	4.9	40.6	51.3	8.1	3.1	12,810
Ohio County						
Beaver Dam						
Ken	9.7	40.9	51.8	7.3	3.0	12,030
EAST KENTUCKY						
Harlan County						
Cawood						
Mill Ridge	3.0	40.4	57.1	2.5	0.8	14,610
Closplint						
Clover	4.2	38.6	58.0	3.4	0.5	14,360
Darby	2.9	40.6	57.1	2.3	0.6	14,860
Crummies						
Closplint	3.3	40.7	57.4	1.9	0.5	14,210
Evarts						
Darmont	5.0	36.8	53.7	9.5	1.0	13,080
TENNESSEE						
Claiborne County						
Clairfield						
Arnold	2.5	38.8	58.3	2.9	0.8	14,370
Fork Ridge	3.4	40.3	56.2	3.5	0.6	14,030
Grundy County						
Coalmont	3.8	29.8	58.3	11.9	0.7	12,820
Marion County						
Palmer	2.7	29.0	61.0	10.0	0.7	13,280
Whitewell						
Reels Cove	2.1	29.3	62.2	8.5	0.6	13,640
Scott County						
Robbins						
Glen May	1.9	37.6	57.6	4.8	0.7	14,370

[a] Taken from Reference 14. Analyses were performed on coals as ready for use.
[b] Washed.

Table 7. ENERGY SOURCES FOR SPACE AND PROCESS HEATING USED BY NASHVILLE FIRMS

Energy source	Number using	Percent using
Gas	207	80
Coal	16	6
Electricity	22	9
Oil	8	3
Wood	6	2
	259	100
No indication	58	---
Totals	317	100

Fourteen firms reported that they used two or more energy sources. Seven of these used gas as the primary source with another fuel as a standby.

Drawing detailed quantitive conclusions on the basis of these fragmentary data is hazardous; however, the number of manufacturing establishments using coal for space and process heating does appear to be small.

The 1958-59 inventory listed 39 educational institutions as using approximately 33,000 tons of coal per year for space heating. Governmental facilities use some 39,000 tons of coal per year. The total of 72,000 tons is about 15 percent of the total yearly local coal consumption and almost 50 percent of the total consumption listed as commercial.

In 1960, about 28,900 housing units in Davidson County were heated with coal. Nearly 18,000 of these units were within the former city limits of Nashville. The Nashville health survey of 1959 shows that 38.6 percent of the dwelling units heated with coal contained hand-fired units. Assuming this percentage to be representative of the former City of Nashville and the rural area, this would amount to 11,000 homes heated with hand-fired coal burning units. The percentage of newer homes heated with hand-fired units would no doubt be less in the urban balance area. An assumption of 25 percent hand-fired units for this area gives a total of 7,200 homes in Davidson County in which 45,000 tons of coal per year is consumed in hand-fired heating plants. According to the 1960 census of housing (Table 3), coal is used in 4,332 homes for cooking and in 2,529 for hot-water heating in Davidson County. An estimated 9,000 tons of coal is used for cooking and hot-water heating. The total amount of coal consumed in hand-fired combustion units is 54,000 tons. In the remaining coal-heated dwelling units, an estimated 80,000 tons of coal is used annually in automatic stoker-fed units.

Means used to provide space heating in dwelling units show a marked difference between the City of Nashville, the urban area outside of Nashville, and the remainder of Davidson County (Table 3). Within the city in 1960, gas was used for space heating in nearly half the homes and almost 35 percent (18,000) were heated by coal. Only 11 percent were heated electrically. In the urban areas outside of Nashville, electric heating was most common, being used by about 53 percent of the homes. Only 25 percent used gas, and 16 percent used coal. In the rural areas, electric heating was used in about half the homes, but gas was used by only about 5 percent. Coal was used in 24 percent and oil in 10 percent of the homes. These data reflect several aspects of the situation:

1. There are more multiple dwelling buildings in the city, and these are more likely to be heated by a central coal-fired unit than are single-family houses.

2. Homes in the city were built during times when coal was the most commonly used fuel. Many original installations are still in use. In urban areas outside of Nashville, homes were built when gas or electric units were more commonly installed for space heating.

3. Conversion of coal-fired units to other means of heating probably has not proceeded so rapidly in the central part of Nashville as in outlying urban areas, partly because the economic means are not generally so available in central Nashville.

4. More homes in Nashville have gas available to them than do homes in urbanized areas outside the city, and even fewer homes in rural areas have gas lines at hand.

In view of these data and the relatively high sulfur and volatile matter content of the coal used, there is no doubt that coal-fired domestic heating and cooking units are a major source of air pollutants, especially smoke and sulfur dioxide, particularly in the Nashville city part of Davidson County.

Natural gas is considered the cleanest of the commonly used fuels. Some pollutants, however, are emitted to the atmosphere when natural gas is burned. The principal pollutants are nitrogen oxides, which are generated when any fuel is burned (Table 5). The consumption of natural gas (Figure 4) has increased from 4.2 billion cubic feet in 1950 to 14 billion cubic feet in 1960. This figure includes three large industrial users who buy directly from the main supply lines. The number of listed consumers has increased, but not proportionately because 3,800 dwelling units of the Nashville Housing Authority are listed as 13 consumers using master gas meters.[16]

MOTOR VEHICLES

The role of motor vehicle exhaust in air pollution is of increasing concern in metropolitan areas throughout the United States. The emissions to the atmosphere from these fuels occur during storage, handling, and consumption. Estimates of the exhaust products discharged to the atmosphere are given in Table 8. The exact amounts and composition are dependent upon engine operating cycles, driving habits, car condition, etc. Other pollutants result from the use of additives such as alkyl lead compounds (tetraethyl or tetramethyl lead) as antiknock agents. Under the influence of sunlight, sufficient concentrations of nitrogen oxides and hydrocarbons in automobile exhaust undergo a series of complex interactions in the atmosphere that form oxidants and other organic compounds, many of which are yet to be identified. These reaction products may cause respiratory irritation, eye irritation, vegetation damage, and rubber deterioration and also form aerosols, which reduce visibility. This type of air pollution is referred to as photochemical smog.

Table 8. ESTIMATES OF EMISSIONS FROM INTERNAL COMBUSTION ENGINES

Pollutant	Pollutant emitted per 1,000 gal. of fuel burned, lb	
	Gasoline engines[a]	Diesel engines[b]
Particulates	11[c]	110[c]
Inorganic gases		
Oxides of sulfur (as SO_2)	5-10	40
Oxides of nitrogen	50-150	160
Carbon monoxide	3000	40
Organic gases		
Aldehydes and ketones	5	11
Other organic gases	2	n
Hydrocarbons	200-400	160

[a] Taken from Reference 17.

[b] Taken from Reference 18.

[c] Data from Reference 19 for particulates only.

n - Negligible.

Most of the pollution from automobiles is discharged through the tailpipe. Hydrocarbons emitted from the crankcase are called "blowby." They constitute from 20 to 40 percent of the total hydrocarbon losses from the automobile. Maximum blowby emissions occur during heavy engine load conditions and the minimum during deceleration. Evaporation from the fuel tank and from the hot carburetor after the engine is stopped, called "hot soak" losses, amount to some 5 percent of the total hydrocarbon losses from the automobile. Fuel tank losses depend upon ambient air temperature.[20]

The steadily increasing number of motor vehicles in Davidson County (Figure 5) reached about 160,000 in 1960. A 1961 report indicated one registered vehicle for each 2.6 persons.[21] For comparison the concentration of automobiles per square mile in several cities is given in Table 9.

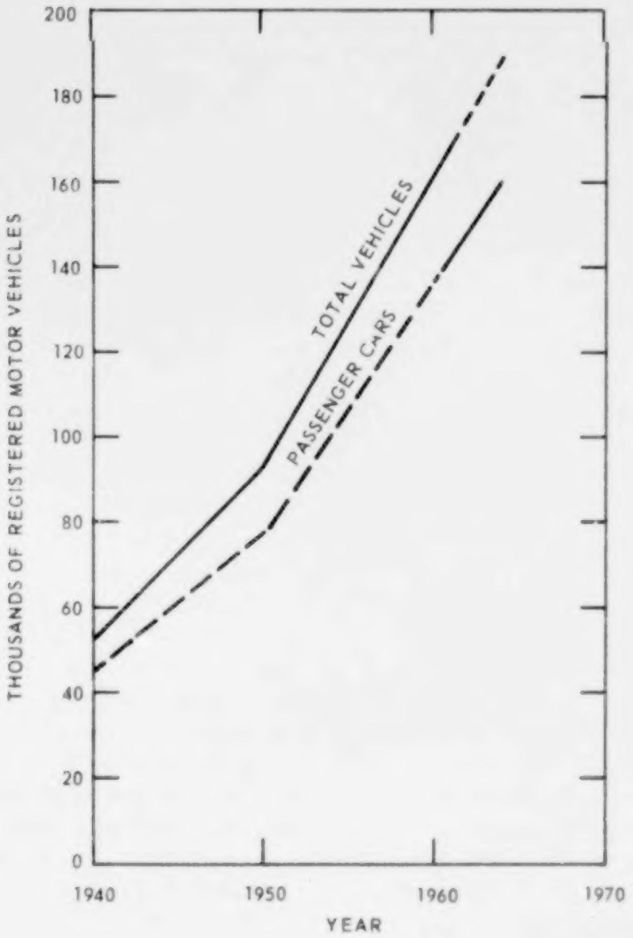

Figure 5. Motor vehicle registration per year in Davidson County.

Table 9. PASSENGER CAR REGISTRATIONS IN NINE METROPOLITAN AREAS, 1960 [a]

Principal city in metropolitan area	Number of passenger cars	Metropolitan area, square miles	Cars per square mile	Persons per car
Atlanta	208,147	523	397	2.7
Chicago	1,476,968	954	1,541	3.4
Columbus	234,340	538	424	2.9
Detroit	955,497	607	1,580	2.8
Los Angeles	2,033,869	1,500	1,350	2.4
Memphis	168,075	751	223	3.7
NASHVILLE	156,455	533	294	2.6
Portland	216,978	424	510	2.4
Washington, D.C.	250,254	61	4,100	3.0

[a] Taken from Reference 20.

Gasoline consumption in Davidson County during 1962 [22] was 124,503,000 gallons. Hydrocarbon emissions from the storage, handling, and use of this gasoline (approximately 1,200 tons per day) are estimated at 61.2 tons per day. The projected estimate of gasoline consumption by 1970 is 149,144,000 gallons per year.

Diesel fuel consumption in the Nashville Metropolitan Area amounts to 3,800,000 gallons per year; 32 percent of this is used by the Nashville Transit Company. [23] Estimates of emissions from diesel fuel consumption are listed in Table 8. The objectionable black smoke frequently associated with diesel exhaust can be reduced greatly by good engine maintenance, use of the correct grade of fuel, and proper operation. Diesel engine operation in trucks, and especially buses, causes odors, which are a frequent cause for complaints by pedestrians and by motorists driving close behind diesel-powered vehicles.

Emission of automobile crankcase blowby can be reduced some 85 percent by installation of a tube that returns these gases to the engine intake manifold for consumption during operation. Starting with 1963 models, such devices were being installed in all American manufactured automobiles. Devices installed by one auto manufacturer have caused difficulty, however, and this company temporarily discontinued blowby device installation in 1964 except on cars for delivery in California and New York, where they are required by law.

By October 1964, four devices for the control of hydrocarbon and carbon monoxide emissions had been approved for installation on new cars and one for installation on used cars, by the California Motor Vehicle Pollution Control Board. Also, the automobile manufacturers have said they will make modifications to the engines of 1966 model cars for delivery in California to reduce emissions to the degree required by California law. Developments in this matter are frequently changing and should be studied continually as they relate to the situation in Nashville.

RAILROADS

Railways have followed a pattern of development that has decreased air pollution. For many years steam locomotives were a major source of smoke, ash, and sulfur dioxide in central Nashville. Steam locomotives in use in 1948 operated during 8,545 hours of switching service and 2,255 hours of road service in the Nashville area. By 1956 these locomotives had all been replaced by diesel units. Furthermore, the major switch yard has now been moved away from the center of the city. These changes have decreased pollution by smoke, ash, and sulfur dioxide considerably.

These reductions in pollutant emissions would seemingly make it possible to establish some new industrial plants that emit sulfur dioxide and particulates without causing a net increase in the air concentration of these pollutants. It is anticipated, however, that this slack will soon be taken up and air pollution controls will be needed to meet the needs for cleaner air in the central part of the metropolitan area. The more this can be met through planning and zoning, the fewer will be the readjustments required through regulatory air pollution control activities.

REFUSE DISPOSAL (SOLID WASTE)

The method of refuse disposal in any community is an important factor in its air quality. A desirable method of refuse disposal that minimizes air pollution and other potential health problems is the sanitary landfill. The Nashville Metropolitan Area had seven such disposal sites in service in 1963. Four of the sites served the City of Nashville and were operated by the City Public Works Department. Other disposal sites were operated by the County Public Works Department. The latter disposal sites were, until July 1, 1961, hampered by lack of equipment and personnel. Maintaining adequate cover material was not always possible, and fires were frequent. The disposal operations have generally improved since more operating personnel and equipment have been made available. Demolition debris and materials not easily compacted are frequently burned at the disposal sites. Properly designed incinerators for this material would eliminate the need for this type of open burning.

Disposal of commercial and industrial refuse is causing some air pollution problems. Open burning of wastes on the premises of some of these establishments is a common practice. Others use incinerators of various kinds, which do a good or poor job of burning the waste, from an air pollution standpoint, depending on design of the incinerator and operating practices. Burning of wastes from building demolition on the site, also a common practice, results in emission of substantial quantities of smoke, ash, and gaseous combustion products into the atmosphere.

Not enough data were accumulated to make a good estimate of air contaminant emissions from burning of refuse; however, a rough estimate was made by assuming that a total of 726 tons of refuse is produced per day (3.5 lb per capita per day [24]), that 75 percent of this refuse is combustible, and that 50 percent of the combustible portion is burned. Using appropriate emission factors from Tables 10 and 11, it was calculated that 10,880 pounds of particulate matter and 65,300 pounds of organic gases are emitted to the atmosphere daily, a major burden to impose on the air resource.

Table 10. ESTIMATED AIR CONTAMINANT EMISSION FROM CERTAIN DOMESTIC REFUSE DISPOSAL PRACTICES

	Contaminant emitted per ton material burned, lb		
	Multiple-chamber incinerators[a]	Backyard trash fires[b]	
Contaminant		Paper only	Garden clippings
Total solids	3.5	4.7	n.a.
Inorganic gases			
Sulfur oxides (as SO_2)	1.8	1.2	n.a.
Nitrogen oxides (as NO_2)	2.2	0.5	0.6
Ammonia (as NH_3)	n	0.1	4.4
Organic gases			
Organics	n	145.0	415.0
Aldehydes (as HCHO)	0.4	2.1	5.7
Acids (as acetic)	n.a.	1.5	n.a.

[a] Taken from Reference 25.

[b] Taken from Reference 26.

n.a. - No reliable data available.

n - Negligible.

Table 11. ESTIMATED AIR CONTAMINANT EMISSIONS FROM CERTAIN MUNICIPAL REFUSE DISPOSAL PRACTICES [a]

Contaminant	Contaminant emitted per ton of material disposed of, lb		
	Incineration	Burning dump	Sanitary landfill
Total solids	19.7	40.0	Variable[b]
Inorganic gases			
Sulfur oxides (as SO_2)	1.7	1.0	--
Nitrogen oxides (as NO_2)	1.8	0.5	--
Ammonia (as NH_3)	0.6	3.0	Trace
H_2S	--	--	Trace
Organic gases			
Organics	1.2	240.0	Trace
Aldehydes (as HCHO)	1.0	3.4	--
Acid (as acetic)	0.5	1.3	--

[a] Taken from Reference 27.

[b] Depends on amount of ashes being placed and amount of dust in cover material. Can be controlled.

ELECTRICAL ENERGY

Use of electricity creates no air pollution at its point of use. In Davidson County, electricity is available at an unusually low cost because of power generated by the Tennessee Valley Authority. Compared with gas, oil, and coal at the consumer level, electricity is more competitive economically in Davidson County and in other areas served by TVA than in most other parts of the nation. This has led to rapidly expanding use of electricity for all purposes, including space heating, a practice which is more prevalent in the TVA area than in most other parts of the United States. Use of electricity in Davidson County has increased from 0.406 billion kilowatt-hours in 1945 to 2.76 billion kilowatt-hours in 1961 (Table 12).

The ever-increasing demand for electricity in the Tennessee Valley will probably be met by additional coal-fired steam-electric generating stations since available hydroelectric power sources in the Tennessee Valley system are presently being utilized almost completely.

There are no major steam-electric generating stations in Davidson County. The nearest one is the TVA plant at Gallatin, Tennessee, about 30 miles northeast of Nashville. This plant uses 1,752,000 tons of coal per year (200 tons per hour). Sulfur dioxide is emitted to the atmosphere at a rate of about 12 tons per hour through 180-foot-high

Table 12. CONSUMPTION OF ELECTRIC POWER IN DAVIDSON COUNTY [a]

Year	Residential use, kw-hr	Non-residential use, kw-hr	Total use, kw-hr	Electric meters
1945	138,919,512	266,937,528	405,857,040	66,603
1950	408,598,358	446,475,122	855,073,480	92,255
1955	810,502,065	690,595,745	1,501,097,810	111,750
1960	1,435,173,277	1,213,629,664	2,648,802,941	128,664
1961	1,479,519,094	1,281,458,155	2,760,977,249	131,342

[a] Taken from Reference 28.

stacks. This is about three times as much sulfur dioxide as is emitted by all sources in Davidson County. Ash emissions are also substantial, even though good dust collecting equipment is used at the plant. Emissions from the Gallatin plant cause some small increase in sulfur dioxide, suspended particulate, and nitrogen oxides concentrations in parts of Davidson County, including Nashville, on days when meteorological conditions are conducive to transporting pollutants from the plant to Davidson County areas.

COMMERCIAL AND INDUSTRIAL SOURCES

The Nashville Metropolitan Area is the urban center for a large region and as such has experienced rapid growth as a manufacturing and wholesale-retail distribution center. Nashville's proximity to the natural resources and raw materials of the central basin of the southern United States has encouraged growth of manufacturing in the area. For example, during 1959, approximately $54,400,000 was invested in new plants and business properties. [21]

There is a wide diversification in products manufactured in the area. Most of the major needs for daily living are represented in the output of local plants. Food, clothing, shoes, lumber and building materials, textiles, appliances, furniture, chemicals, printing, engraving, foundry products, and metal fabrication are some of the major groups of products and services of the Nashville Metropolitan Area. The manufacturing complex is made up of more than 520 establishments of various sizes. A generalized description of the air pollution from this complex is listed in Table 13.

In February 1962 the Davidson County Health Department sent a questionnaire entitled "Inventory of Air Contaminant Emissions of Commercial and Industrial Sources" (Appendix A) to 529 firms listed in the 1962 Directory of Nashville Manufacturers. [15] The completed

Table 13. SUMMARY OF INDUSTRIAL AND COMMERCIAL AIR POLLUTION SOURCES [a] IN NASHVILLE METROPOLITAN AREA

Industry	Number of plants	Contribution to air pollution problems
Stone, clay, and glass products	38	Dust from ready-mixed concrete, concrete products, quarrying, glass manufacturing, cement manufacturing, asphaltic concrete. Frequent complaints, major contribution.
Chemical and allied products	33	Wide variety of pollutants depending upon technology involved; aerosols, vapor, odors. Localized complaints, minor to significant contribution.
Food and food products	88	Odors from meat packing, processing, and rendering plants and coffee roasting; dust from feed grinding and mixing operations. Localized complaints, minor to significant contribution.
Lumber and wood products	47	Smoke from burning wood wastes and sawdust, dust from milling and sawing operations, solvent odors and spray paint mist. Localized complaints, minor contribution.
Machine shops and metal products fabrication	85	Solvent odors from degreasing and spray painting, spray painting mist, grinding wheel dust. Localized complaints, minor contribution.
Metallurgical processes	8	Metallic oxides, dust, smoke, gases from ferrous and nonferrous casting operations. Localized complaints, minor contribution.
Printing, publishing, and advertising	110	Solvent odors, lead fumes. Few localized complaints, minor contribution.
Textiles, leather goods, paper, and rubber products	44	Lint, dust, and fines from production waste; organic vapors from dyeing, bleaching, cleaning, and cementing. Few complaints, minor contribution.
Electronics and instrument assembly	15	Emissions usually controlled, but may produce smoke, dust, or acid mist emission. Few complaints, negligible contribution.

[a] The contribution to air pollution by fuel consumption is not included (see Table 5).

questionnaire was returned to the Nashville Department of Public Works, Division of Smoke Regulation, by 60 percent (317) of the firms. Information provided by the responding firms was used to assess the emissions from the commercial and industrial sources in the area.

As a means of accounting for all commercial and industrial pollution sources in the area, the returned questionnaires were cross-checked with the 1962 Directory of Nashville Manufacturers. A direct contact was then made with all firms that did not reply originally, provided their type of operation indicated probable significant emission of air pollutants. The emission inventory is therefore a total assessment of the emissions from all the commercial and industrial sources in the area.

To make a precise determination of pollutant emissions, each case must actually be measured. In some cases, however, emissions can be estimated on the basis of production of finished goods, or on the amounts and kinds of raw materials used. Established emission factors are applied to relate pollutant emission rates to such information. These factors were developed through actual testing of pollution sources. Sampling of the effluent of pollution sources in Davidson County was impractical in the present studies; therefore, the emission inventory for this report was compiled with the information given by questionnaires and the best available data from the literature. Emissions from a specific establishment, when determined in this fashion, are only rough approximations since operations vary widely. If, however, a sufficient number of operations are covered, errors involved with small samples tend to disappear and the degree of accuracy of the emission value for a group of plants engaged in similar processes approaches the true mean value. The emission inventory, when correlated with aerometric and meteorological data, provides the basic information for determining many future air resource management activities.

Mineral Industries - Stone, Clay, and Glass

Dust generated by mechanical crushing, grinding, screening, transferring, and drying of various materials are the pollutants of major concern in this group. Concrete batching plants, asphalt mixing plants, rock quarry operations, etc., are frequently the source of widespread complaints.

By the general nature of these operations, there are many points for release of dust to the atmosphere. The copious use of water, enclosed systems, and flexible sleeves can greatly reduce the release of dusts. These control methods require constant maintenance and surveillance on the part of management, which are sometimes neglected in operational haste. There is also a tendency to overload some kinds of plants because of the seasonal fluctuations in product demand.

The cement manufacturing industry has been using gas cleaning devices on the waste gases from rotary kilns for some time. These control devices may be such items as cyclones, electrostatic precipitators, or fabric filters. Depending upon product specifications, the collected dust is usually returned to the kiln.[29]

The solid particulate matter emitted from the mineral industries in the Nashville Metropolitan Area amounts to about 33 tons or 41 percent of the total in the area per average working day (Table 14). This does not mean that the emissions are in fact uniform for they tend to be higher during the warmer seasons because of the increased product demand. Rock quarrying and crushing operations are not included in this estimate because no reasonable emission factors are available. Emissions from the mineral industry can be greatly reduced by utilization of appropriate equipment and procedures. For example, in the Los Angeles Air Pollution Control District, dust emission from 50 asphaltic road mix batching plants with air pollution control equipment is only 3 tons per day. If controls were not in use, emissions would be about 34 tons per day.[25]

Isolation by the application of restrictive zoning is generally an effective means of reducing nuisance complaints. The experience of other areas indicates that the stone and clay industries can be operated in a manner compatible with surrounding development, but that a reasonable amount of planned isolation tends to decrease the number of local problems.

Wood and Wood Products Industries

The primary air pollutant in the lumber and wood products industry is smoke, which results from the burning of sawdust and wood waste. Organic vapor emissions from painting and varnishing operations are of secondary importance, but add to the total load of air pollutants.

In the Nashville area these operations produce over 126 tons of sawdust and wood waste per day. With proper equipment and operational care, these materials can be disposed of without excessive pollution in the following ways: burned in a waste heat boiler, utilized to make other products, incinerated, or placed in sanitary landfills. Eight of the reporting plants in Nashville burn their sawdust and wood waste in waste heat boilers, which have the advantage of recovering energy in the form of steam from waste material. The boilers in Nashville, however, often produce large quantities of smoke because wood contains about 50 percent volatile matter and combustion is inefficient in burners not properly designed for this fuel, especially those that are hand-fired. Hydrocarbon emissions from these sources were estimated at roughly 334 tons per year (Table 14). This figure was established by using an emission factor based on source test data on silo-type incinerators.[30, 31] Acceptable burning of wood wastes would probably mean that much of the existing equipment would have to be modified

Table 14. SUMMARY OF ESTIMATED PRINCIPAL POLLUTANT EMISSIONS IN NASHVILLE METROPOLITAN AREA[a] (Data in tons per year)

Pollutants	Natural gas	Coal	Petroleum fuels	Gasoline consumption	Gasoline handling losses	Diesel fuel consumption	Wood waste burning	Chemical industries	Refuse burning[b]	Stone, clay, and glass industries	Other sources	Partial total
Aldehydes	283	c	23	311	0	9	30	n	169	0	0	825
Nitrogen oxides	2,542	1,387	710	6,225	0	328	21	19	25	0	0	11,257
Organic gases	51	1,787[d]	23	18,800	3,673	328	334	1,755	11,914	0	1,361	40,026
Sulfur oxides	12	28,950	882	498	0	82	2	n.a.	50	0	3,590[e]	34,066
Solids	n	6,789	134	685[f]	0	209[f]	43	1,384	1,982	8,510	1,638	20,581
References used for emission factors	10	10	11	12 79[f]	13	14 79[f]	15 16	- -	- -	17 18	- -	- -

[a] Does not include carbon monoxide or carbon dioxide unless otherwise indicated; also does not include pollutants emitted in relatively small total quantities. Pollution emissions from fuel consumption are not included in emissions from industries and other sources, but are listed in their respective column.

[b] Assumption.

[c] Included in organic gases.

[d] Combustible gases (CH_4, CO, H_2, etc.).

[e] Total process sulfur dioxide emission as given in the 1958 SO_2 emission inventory.

[f] Reference applies only to solids.

n - Negligible.

n.a. - Not available.

and wood waste storage bins and constant-rate continuous-fuel-feeding systems would have to be installed.

Most of the other firms burn their wood waste in barrel-type incinerators or open pits. These methods of disposal do not produce complete combustion; considerable smoke and ash emissions result, and local complaints are frequent.

Chemical Industry

The chemical industry is the most diversified of the industrial classifications; thus, making an accurate emission inventory is extremely difficult. It is also one of the fastest growing industries and the spawning ground for new technology, which frequently necessitates process modification and sometimes a complete change in production activity, which in turn may rapidly alter the type and quantity of emissions.

Because of the toxic nature of some of the materials used, air pollution control measures are often employed. Since the material lost may have direct monetary value, production economics dictate an awareness of the extent of losses and possible product recovery. Because of the magnitude of these operations and the objectionable nature of many emissions, the contribution to the community air pollution problem can be significant. Chemical industry activities in the Nashville area result in emissions of about 5.3 tons of particulate matter and 6.7 tons of organic gases per working day (260 working days per year). Table 14 summarizes principal emissions on an annual basis.

Metallurgical and Metal Fabrication Industries

The metal industries of the Nashville Metropolitan Area are of minor importance in their overall contribution to air pollution. In melting scrap metal and ingot, foundries emit smoke, dusts, metallic fumes, and combustion products from the fuel used to support the process. The particulate matter emissions reduce visibility and produce soiling, both of which cause frequent local complaints. This is a small-scale operation. The total castings amounted to only 35 tons of material per day by the four reporting firms.

Emissions from the metal fabrication, plating, and electronic industries are organic solvents from painting and degreasing operations, paint and acid mists, lubricating oil mists, and grinding dust. The total solvent emission from the metals industry is approximately 173 tons per year.

Solvents

The use of solvents is so extensive that it is difficult to name a manufactured product made without their use. They are used in considerable quantities in paints, varnishes, enamels, stains, printing inks, etc., and in the cleaning industry. Unless special preventive means are employed, nearly all the solvent in these products enters the atmosphere. The control of solvent vapor emissions has not been widely practiced because of the dilute concentrations in the effluent gases from the operations involved. Control, however, can be accomplished by direct-flame incineration, catalytic incineration, adsorption, scrubbing, or condensation. The adsorption of organic solvent vapors upon activated-charcoal presently appears to be one of the more promising methods of control.

The role of solvents in atmospheric photochemical smog reactions is a field of serious interest. The relative importance of the various solvents has not been fully established, but many are involved in reactions that produce compounds having detrimental effects.

Printing

Some 7,000 people are employed by more than 80 firms of the printing and publishing industry. This is larger than normal because Nashville is a center for publishing religious literature. Emissions to the atmosphere from this industry are mainly organic solvents from inks and lead fumes from the melting pots of typesetting machines. Solvent emissions vary in quantity and kind, depending on the method of printing and the type of ink used. The solvent content of ink varies from none in newspaper ink to 35 to 40 percent in the heat-set inks used in the rotogravure process. In Nashville the most common ink used is a quick-set ink, which contains about 10 percent solvent. Although emission of solvents by this industry is relatively low for the magnitude of operations, it still amounts to an estimated 1.15 tons per day.

Dry Cleaning

Dry cleaning is a commercial operation from which a considerable quantity of organic solvents is emitted. There are about 35 commercial dry cleaning establishments in the metropolitan area, two-thirds of which do their cleaning with perchloroethylene. The remaining plants use Stoddard Solvent or some other aliphatic hydrocarbon mixture. The total solvent emissions to the atmosphere from this industry amount to 2.21 tons per day, 1.66 tons of which are aliphatic hydrocarbon mixtures. Solvent consumption amounts to approximately 1 gallon of perchloroethylene per 164 pounds of clothes cleaned, or 1 gallon per 34 pounds of clothes when Stoddard Solvent is used. Because of the high cost of solvents, it is common practice, when using perchloroethylene, to reduce losses by installing vapor recovery equipment (usually condensation type).

Textile and Leather

The textile and leather goods industry can be the cause of local problems from the emission of lints, fine dust, organic vapors, and mists. Although it is a rather large part of the industrial complex of this area, it is a minor contributor to air pollution.

Food and Food Products

Emissions from the food and kindred products industry are usually in the form of odors. Certain operations, such as coffee roasting, food drying, and meat smoking, give rise to visible and odorous emissions. Although the total contribution is small in terms of weight, food industry emissions cause frequent and persistent complaints.

Fine particles from grain handling and feed grinding operations are often the cause of local complaints. Of the six reporting firms in the Nashville area, daily average production was 1,175 tons. About 0.5 percent or, 11,149 pounds, per day is lost to the atmosphere. At $3.00 per hundred pounds, it amounts to a recoverable loss of $91,300 per year.

DISCUSSION OF SOURCES OF AIR POLLUTANTS

A summary of estimated emissions of air pollutants was prepared on the basis of information contained in the foregoing sections (Table 14). These data are only rough estimates and do not include all emissions to the atmosphere in the area, but the data in Tables 13 and 14, along with the foregoing information, are sufficiently valid to support the following conclusions.

1. Sulfur dioxide arises mainly (about 85 percent) from the use of coal. The coal is used in about equal amounts for (a) residential space heating, (b) commercial and industrial space- and water-heating and power generation, and (c) industrial process heating.

2. Particulate matter is emitted largely from industrial processes, coal-fired heating plants, and refuse burning operations. Particulate from burning of coal and refuse contains a high proportion of small-sized smoke particles, which tend to remain suspended in the air for a long time. The industrial process dusts, in general, consist of a high proportion of fairly large size particles, which tend to settle out of the atmosphere in a comparatively short time.

3. Emissions of organic gases (mainly hydrocarbons) are attributable largely to use and handling of gasoline and to refuse burning.

4. Nitrogen oxides are emitted mainly from motor vehicles and natural-gas-burning furnaces.

5. Localized dust and odor nuisances are attributable mainly to industrial operations and refuse burning.

AIR QUALITY IN NASHVILLE AREA

AIR QUALITY MEASUREMENTS MADE

Over 200,000 aerometric measurements were made in the Nashville Metropolitan Area from July 1958 through August 1959. Measurements are summarized in Table 15. Other special measurements were made at various times.

The study area included the City of Nashville and the surrounding urbanized area. Aerometric stations were established at 123 sites (Figure 2). Of these, 119 were located at the intersection of lines forming an equilateral-triangle grid pattern. These stations covered an area about 9 miles in diameter, centered around Ninth and McGavock Streets in downtown Nashville (Station 60). Control stations were located in the four cardinal compass directions from the central station and about 3 miles beyond the station network. Specific station locations are listed in Appendix B. Figure 6 shows a picture of a Type I aerometric station. The equipment was mounted on utility poles about 11 feet above ground. These stations were about 0.87 mile apart. Type II stations using equipment mounted on utility poles (Figure 7) were established at 25 locations. Type III stations (Figure 8) were established at 11 locations, including four control stations in semirural areas. Details of the studies conducted can be found in Reference 1.

DUSTFALL

More than 1,400 dustfall samples were collected at 119 urban stations during the aerometric survey. Each sample represented a 1-month accumulation of settled dust. Results are shown on Figures 9, 10, and 11.[32] The data shown cannot be compared directly to data from most other studies because in this report, geometric means are used and because only water insoluble dustfall is reported. In most studies done elsewhere, arithmetic means used to express averages usually result in a higher mean than if the geometric means are used.[33] Most surveys report total water soluble and water insoluble dustfall, which always gives a value higher than if only water insolubles are reported. The Nashville data for water insoluble dustfall may be converted to include both kinds of dustfall approximately by multiplying by 1.8.

Table 15. SUMMARY OF ROUTINE AEROMETRIC PROGRAM, NASHVILLE AIR POLLUTION STUDY

Station	Number of stations	Measurements made	Equipment	Frequency of measurement	Analyses made	Analytic method	Remarks
Type I	87	Dustfall	Plastic dustfall collectors - wet bottom	One 30-day sample per month	Weight of water insoluble matter	Filter contents of collector, dry, and weigh	Sampling equipment mounted on utility poles
		Sulfur dioxide	Lead peroxide candle	One 30-day sample per month	Sulfur trioxide determined as sulfate	Barium chloride method for sulphate, gravimetric	
Type II	25	MEASUREMENTS MADE AT TYPE I STATIONS ALSO MADE AT ALL TYPE II STATIONS					
		Soiling (Suspended particulate)	Sampling train of filter paper, bubbler, trap, orifice, and pump	One 24-hour sample per day	Change in light transmission through filter paper	Photometric	Sampling equipment mounted on utility poles
		Sulfur dioxide		One 24-hour sample per day	Sulfur dioxide	West and Gaeke method	Laboratory analyses made using Technicon Autoanalyzer
		Total wind movement	Airways Weather Bureau No. 402 Odometer	One 24-hour total per day	Total wind movement per 24-hour period	Automatic counter read daily	Sensing elements about 33 feet above ground
Type III	2	MEASUREMENTS MADE AT TYPE I AND TYPE II STATIONS ALSO MADE AT ALL TYPE III STATIONS					Dustfall also analyzed for water soluble benzene soluble; other combustible, ash
		Suspended particulate	High-Vol filter paper sampler	One 24-hour sample per day	All samples - total weight of particulate matter	Gravimetric	Benzene extracts of many samples fractionated and used for animal studies of possible carcinogenicity
					One sample in ten - further analyses made for total organic, nitrate, and sulfate	As used in U.S. Public Health Service National Air Sampling Network	
		Soiling (Suspended particulate)	AISI strip filter paper sampler	Twelve 2-hour or six 4-hour samples per day	Change in light transmission through filter paper	Photometric	2-hour samples in high pollution seasons 4-hour samples in low pollution seasons
		Sulfur dioxide	Automatic sequential sampler with midget bubblers	Twelve 2-hour samples per day	Sulfur dioxide	West and Gaeke method	Atmospheric air filtered before passing through bubbler. Laboratory analyses made using Technicon Autoanalyzer
Type III M	4	MEASUREMENTS MADE AT TYPE III STATIONS ALSO MADE AT ALL TYPE III M STATIONS					
		Wind speed, wind direction	Beckman and Whitley Model K 100 wind system	Continuous strip chart record	Wind speed - average, maximum, and minimum hourly Wind direction - average, highest veering and backing direction - all hourly	Strip chart observation and data reduction	Sensing elements about 33 feet above ground. Fifth highest veering and backing direction used August 1958 through January 1959.
		Temperature, relative humidity	Friez Hygrothermograph Model 594	Continuous strip chart record	Average hourly values taken from charts	Strip chart observation and data reduction	Instrument in Weather Bureau Cotton Region type shelter.

Type III C	4	MEASUREMENTS MADE AT TYPE III STATIONS WERE MADE AT ALL TYPE III C STATIONS EXCEPT THAT 2-HOUR SULFUR DIOXIDE MEASUREMENTS WERE NOT MADE					
Type III X (Central Station)	1	MEASUREMENTS MADE AT TYPE III STATIONS MADE ALSO AT THE TYPE III X STATION					
		Sulfur dioxide	Thomas Autometer	Continuous strip chart record	Sulfur dioxide	Change in electrolytic conductivity of hydrogen peroxide - sulfuric acid absorbing solution	
		Nitrogen dioxide	Kruger Model 73 Atmosphere Analyzer	Continuous strip chart record	Nitrogen dioxide	Automatically recorded colorimetric analysis based on method described by Saltzman	Nitric oxide channel of recorder not operated successfully
		Oxidant			Oxidant	Automatically recorded colorimetric analysis based on neutral KI reaction	
		Carbon monoxide	M.S.A. Luft type nondispersive infrared analyzer	Continuous strip chart record	Carbon monoxide	Absorption of infrared radiation converted to electrical output signal	
		Suspended particulate matter collected	Positive displacement pump, sheets of membrane filter media	Sampler run continuously. Each filter used 2 - 4 weeks	Particulate matter mechanically removed for use as collected		Collected material used for animal studies of possible carcinogenicity
Cordell Hull Building		Visual range	Human observer	0900 and 1500 CST daily		Visibility of certain objects at known distances away was noted	
		Photographs	Camera	0900 and 1500 CST Daily		Appraisal of degree of haze as shown on pictures	Picture taken in three compass directions
		Incoming radiation	Instrument Corp. Actinometer	Continuous strip chart record	Average hourly total incoming radiation	Instrument operates on a differential heating principle	
Television Tower	1	Upper air wind speed wind direction	Bendix-Friez Aerovane	Continuous strip chart record	Same as at Type III M stations	Same as at Type III M stations	Sensing units at 251.5 and 501.5 feet above ground - recorder at ground level
Downtown park area	1	Net radiation	Suomi Economical Net Radiometer	Four times per minute recorded	Net radiation. (Difference between incoming solar and sky radiation and outgoing terrestrial radiation)	Output of thermopiles recorded	Located in small park area near downtown area near Cordell Hull Building
U.S. Weather Bureau Airport Station, Berry Field	1	Upper air winds	Pilot balloons and rawinsonde	Four per day at 0600, 1200, 1800, and 2400 CST	Wind speed and direction at specified levels		Pilot balloons at 1200 and 2400 CST Rawinsonde at 0600 and 1800 CST
		Sunshine	Marvin Sunshine Recorder	Continuous strip chart record	Minutes of sunshine each hour	Instrument is a differential air thermometer	
		Upper air temperature, pressure, relative humidity	Radiosonde units	0600 and 1800 CST daily	Temperature, relative humidity, and pressure in upper air		Other measurements usually made at USWB first order stations are available

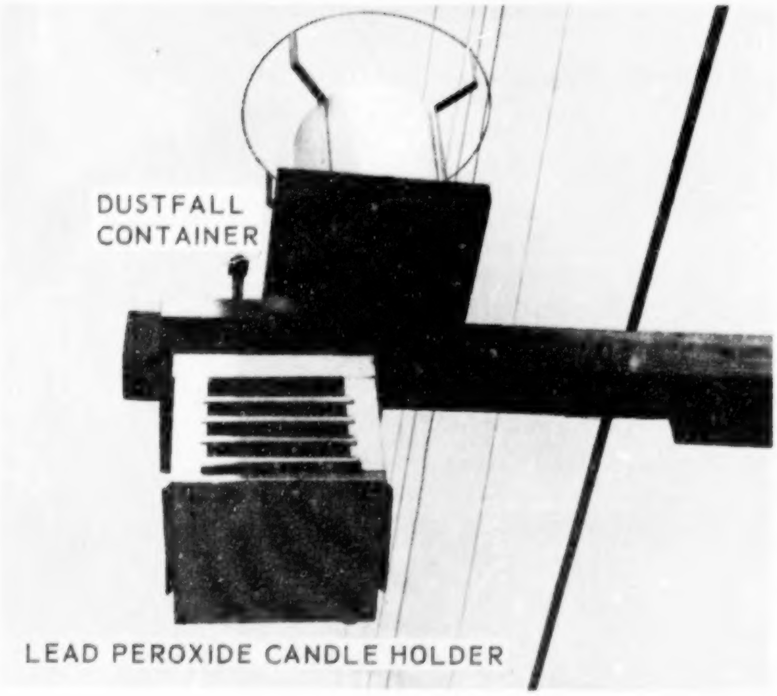
DUSTFALL CONTAINER
LEAD PEROXIDE CANDLE HOLDER

Figure 6. Typical type I aerometric station. See Table 15 for measurements made.

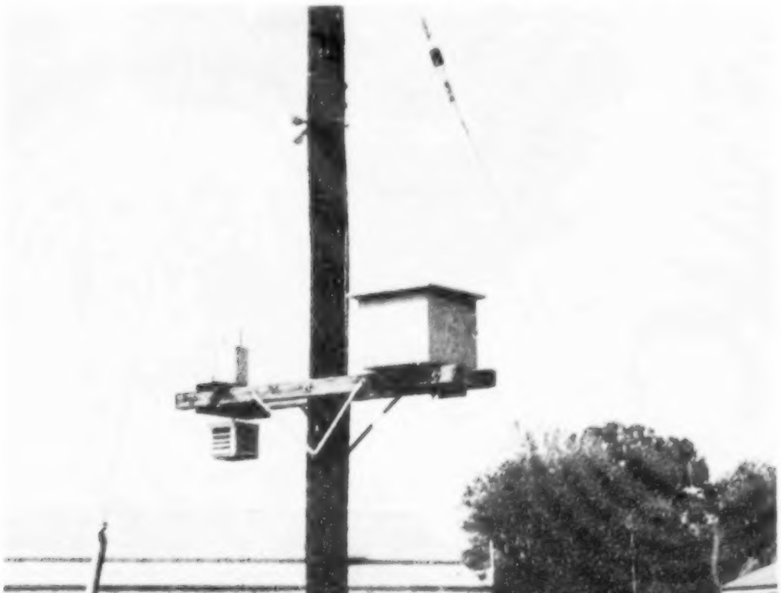

Figure 7. Type II aerometric station (anemometer on top of pole not visible). See Table 15 for measurements made.

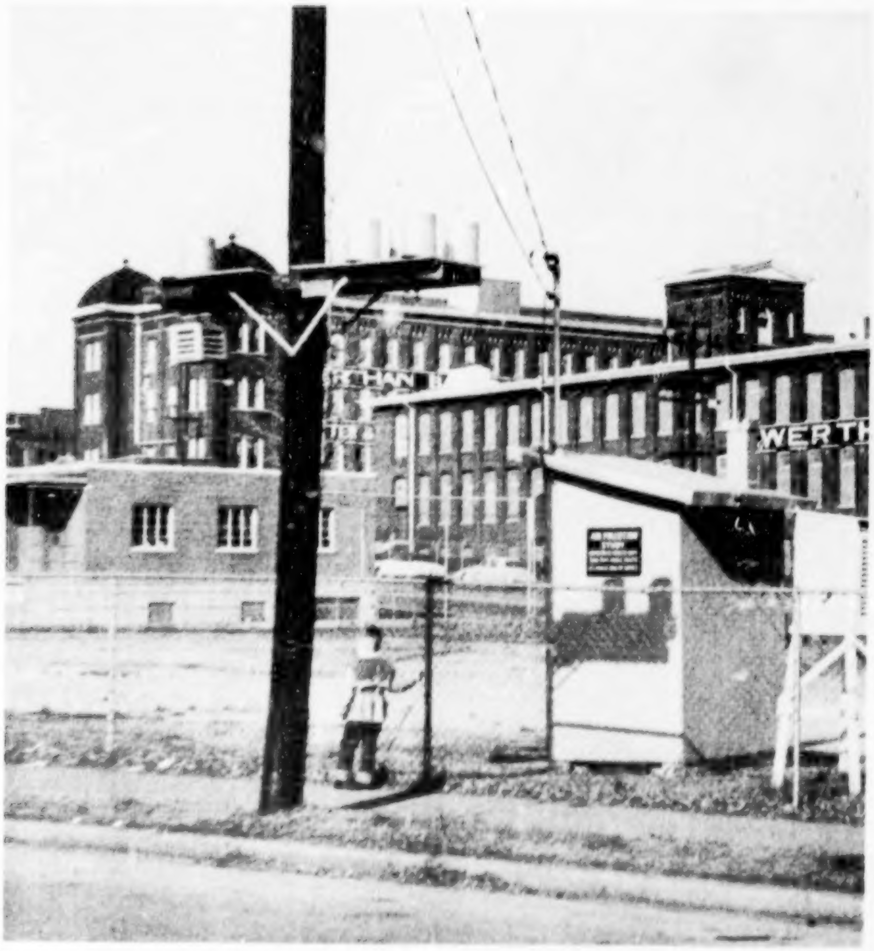

Figure 8. Type III aerometric station. See Table 15 for measurements made.

Area-wide average insoluble dustfall ranged from about 5 tons per square mile per month in January and May to about 9 in April. Seasonal averages over the study area did not vary much, ranging only from about 6 to 7 tons (Figure 9). There is no doubt that emission of particulate matter collected in dustfall samplers is greater during colder months than during warmer months because of furnaces used for space heating. The data indicate, however, that this increased emission in colder months is balanced by greater dust generation from some other cause in the warmer months. Sources that might be responsible for greater contributions in warmer months include construction work, concrete batching plants, and asphaltic road mix plants. Also, wind-blown surface dust is greater in warm months because the earth is drier and dustier.

Dustfall in the Nashville area varies considerably from place to place as it does in most other communities. Annual averages for insoluble dustfall ranged from less than 5 to more than 15 tons per square

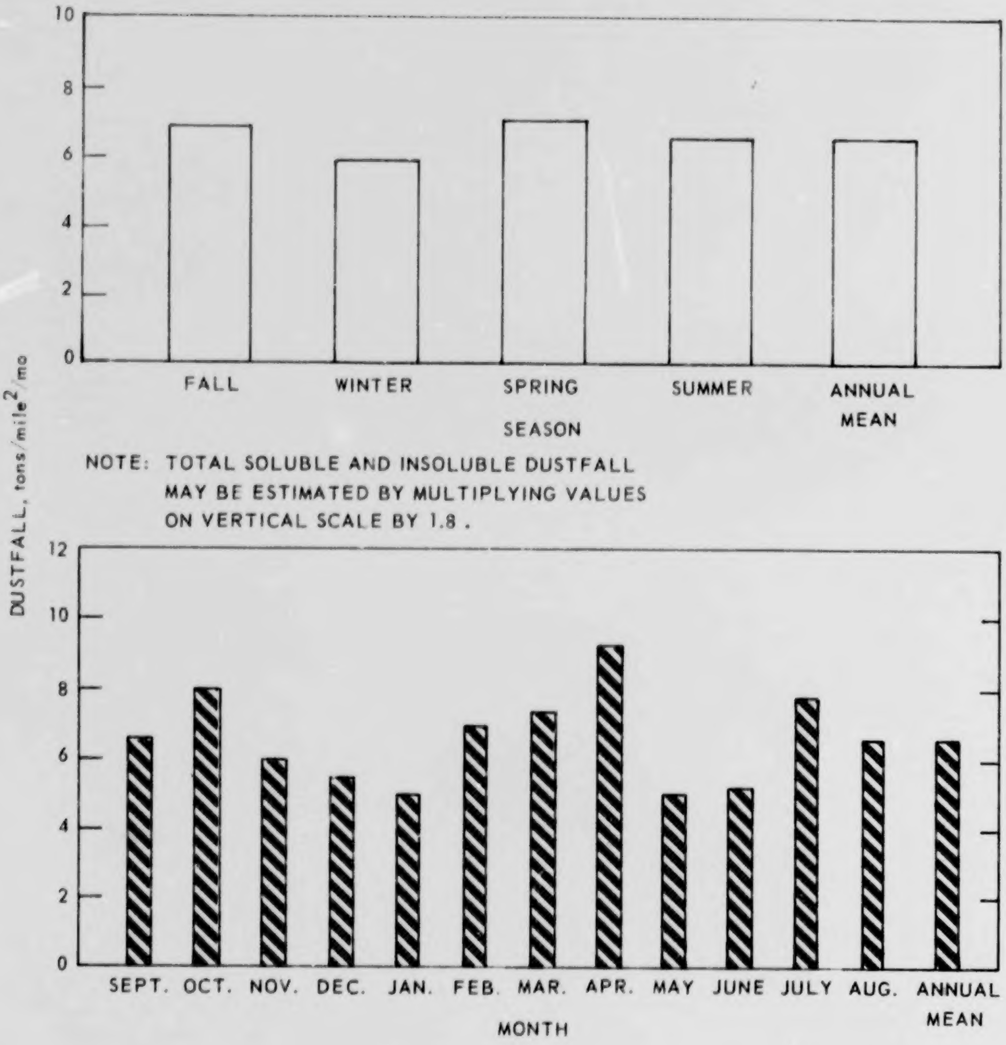

Figure 9. Geometric mean of water insoluble dustfall determined by 119 sampling stations (See Reference 32).

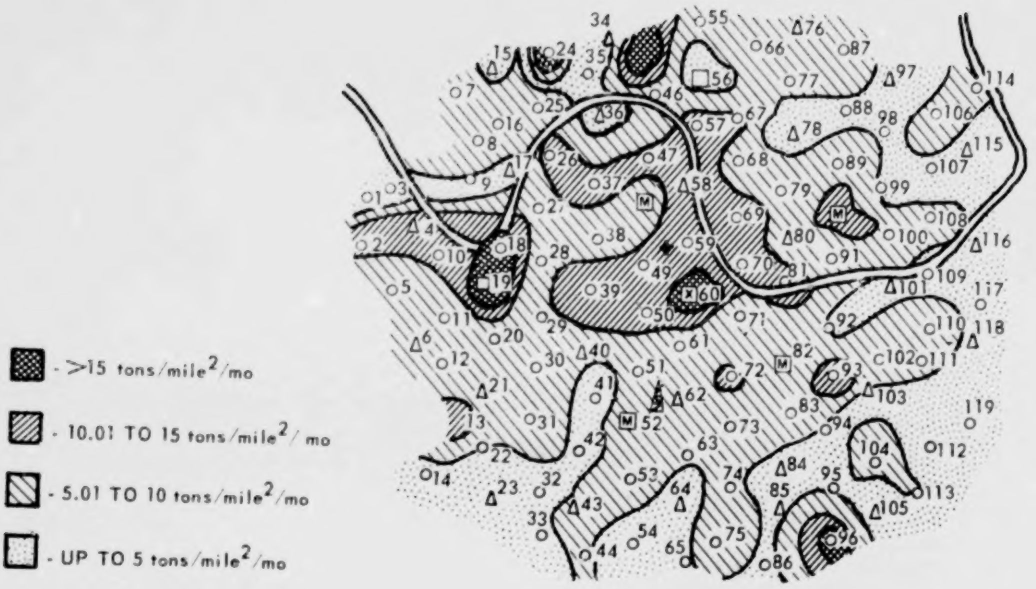
▩ - >15 tons/mile²/mo
▨ - 10.01 TO 15 tons/mile²/mo
▧ - 5.01 TO 10 tons/mile²/mo
☐ - UP TO 5 tons/mile²/mo

Figure 10. Annual geometric mean dustfall determined by network of 119 stations (See Reference 32).

mile per month (Figure 10). This reflects the fact that much of the dust that falls at a particular site is most often discharged into the air from a source nearby.

A reasonable value to use as a maximum permissible dustfall rate averaged over a year, of the type reported herein, is 10 tons per square mile per month (water insoluble portion only). This value should relate to the yearly average for any one station located at a place where people live or where an undesirable effect would result. Higher rates of dustfall are associated with excessive soiling of porches, window sills, automobiles, etc., by settled dust. The dustfall measurement method and the small number of samples collected do not justify full interpretation of data; however, if the rate of dustfall is highly variable, yearly means or even monthly accumulative samples will not be adequate measures of the actual problem. The number of people living in areas with various dustfall rates (as shown on Figure 10) was determined. A total of 120,000 people lived in areas with dustfall rates of 10 to 15 tons per square mile per month, and 5,500 people lived in areas with more than 15 tons per square mile per month. These latter areas are considered excessively dirty.

Annual average dustfall rates are one basis for judging such pollution; however, dustfall rates may vary considerably from month to month at a particular location. Figure 11 depicts this variation. It can be seen that total dustfall for the area in general does not vary much

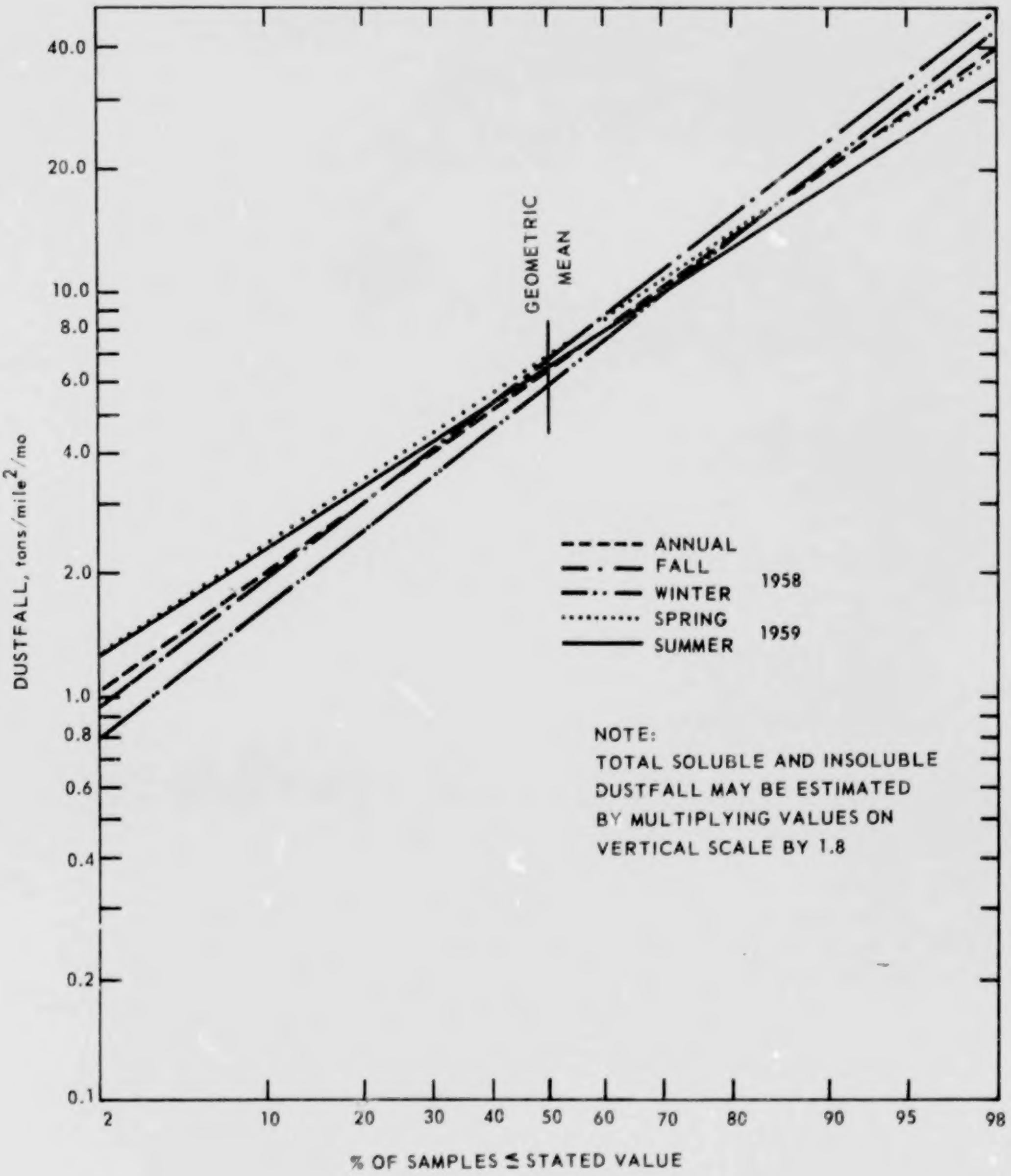

Figure 11. Cumulative frequency distribution of water insoluble dustfall determined by 119 sampling stations (See Reference 32).

from one season to another. The figure also shows that almost 30 percent of the 1,400 individual samples collected corresponded to 10 tons per square mile per month and that in 10 percent of the samples, a dustfall of 20 tons per square mile per month, or higher, was found.

In summary, dustfall is not a major and general problem in the area. There are, however, rather large areas in which dustfall is somewhat greater than desirable and some limited areas with dustfall far in excess of desirable levels.

TOTAL SUSPENDED PARTICULATE MATTER

Suspended particulate matter was collected by use of Hi-Vol filter paper samplers. The amount of particulate matter was determined by weighing the filter before use and after ambient air had been drawn through it for 24 hours. The increase in weight was due to particles removed from the air passing through the filter. Samples were collected daily for a year at seven stations in the urbanized area and at four control stations in semirural areas about 3 miles beyond the urbanized areas. Results are summarized in Figures 12 and 13 and Table 16.[34]

The U.S. Public Health Service, in cooperation with state and local governmental agencies, operates Hi-Vol filter paper samplers in over 200 cities of the United States in a program called the National Air Sampling Network. Data from cities of various sizes collected during 1957-1961 are shown in Figure 14. Cities the size of Nashville (100,000 to 400,000 population), on the average, experience an atmospheric particulate loading of 101 micrograms per cubic meter.[35] Nashville's

Table 16. AVERAGE ANNUAL AND SEASONAL GEOMETRIC MEANS OF SUSPENDED PARTICULATE MATTER

	Particulate, $\mu g/m^3$
Nashville 1958-1959[a]	125
Comparable U.S. cities 1959[a]	101
Nashville seasonal average[b]	
Fall	141
Winter	135
Spring	119
Summer	107

[a] National Air Sampling Network cities with 100,000 to 400,000 population.

[b] Seven urban stations.

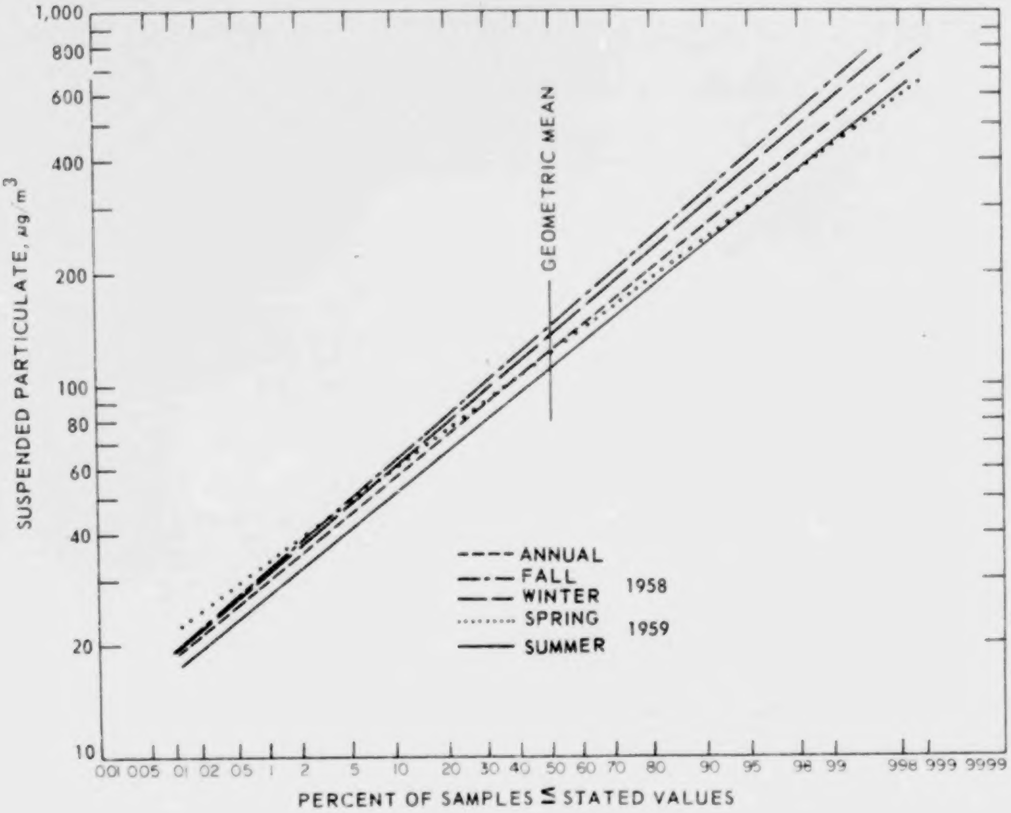

Figure 12. Cumulative frequency distributions of suspended particulate matter at seven stations in urban area (See Reference 34).

average of 125 indicates that for a city its size, Nashville has an unusually high loading of particulate matter in its air.

Atmospheric particulate matter over the Nashville area ranges from 107 micrograms per cubic meter in the summer to 141 in the fall, and 135 in the winter (Figure 12 and Table 16). The higher concentrations in the fall and winter reflect the greater emission of smoke

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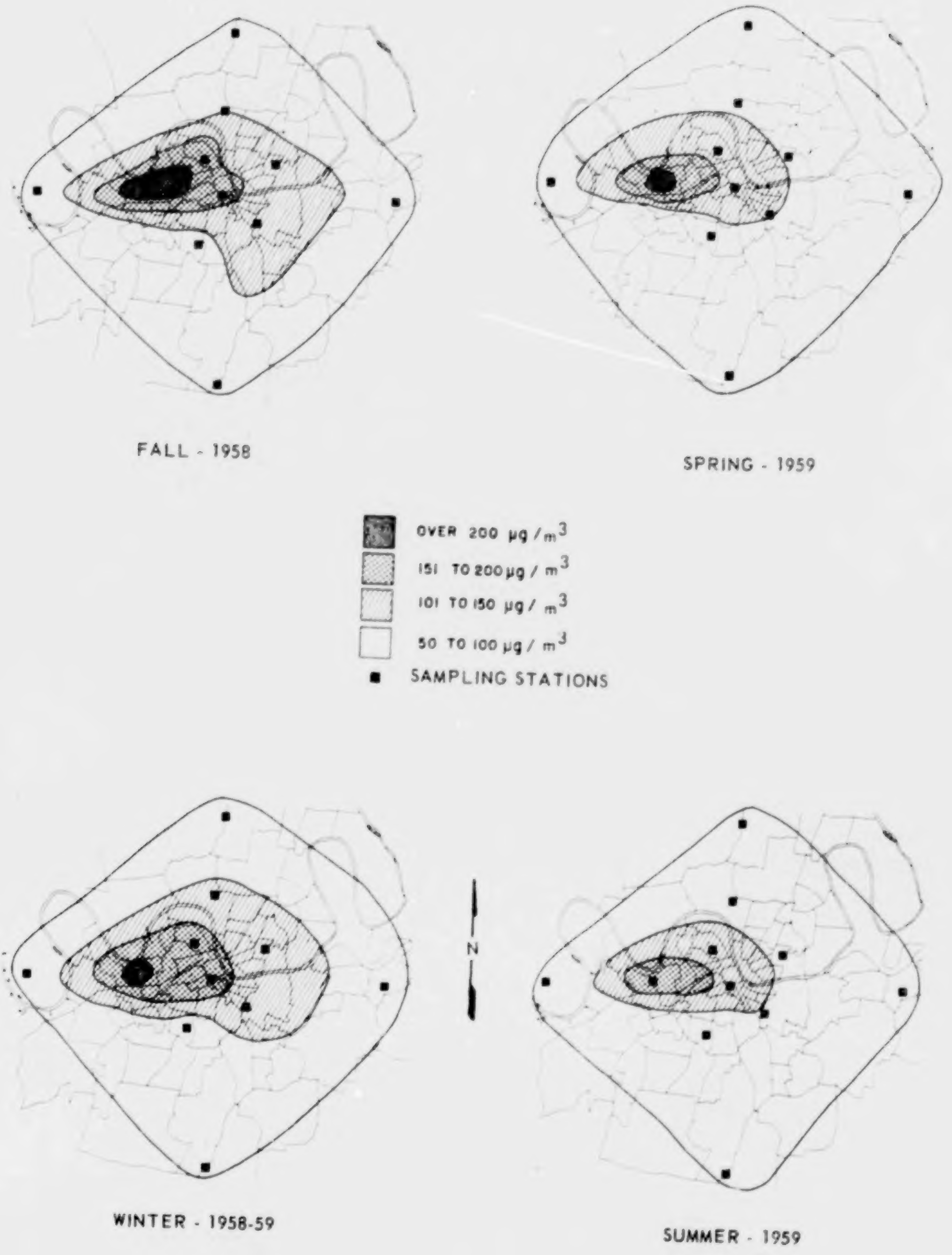


FALL - 1958

SPRING - 1959

WINTER - 1958-59

SUMMER - 1959

OVER 200 µg / m3
151 TO 200 µg / m3
101 TO 150 µg / m3
50 TO 100 µg / m3
SAMPLING STATIONS
N

Figure 13. Seasonal geometric mean suspended particulate matter (See Reference 34).

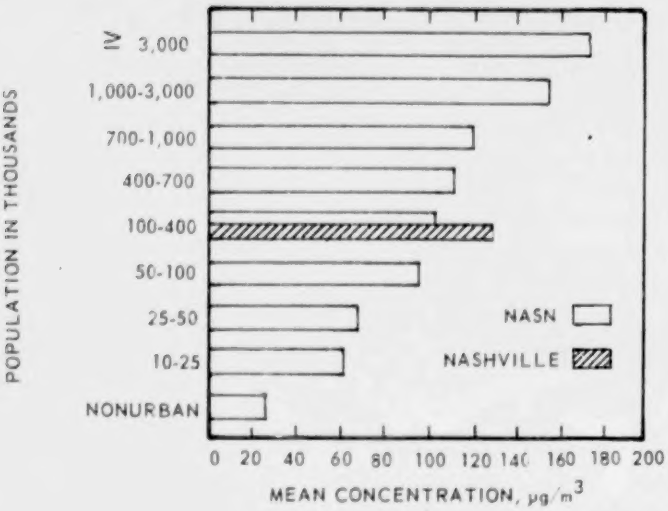


Figure 14. Mean concentration of suspended particulate matter by population of cities, 1957-1961, and Nashville 1958-1959.

and ash from coal-fired furnaces used for space heating. Also, meteorological conditions are less favorable for dispersion of pollutants in the fall season.

The number of people living in areas with various suspended particulate loadings was determined on the basis of Figure 13 and population statistics. About 77,000 residents of the Nashville area live in a 13.2-square-mile area where the annual geometric mean particulate loading is in excess of 150 micrograms per cubic meter. About 7,200 people live in areas where the annual geometric mean particulate loading is in excess of 200 micrograms per cubic meter. These areas of high and very high pollution are located in the central and west-central part of the urban area (Figure 13). This is the area where many coal-fired heating plants are located; the coal consumption explains, at least in part, the high pollution levels. Topographic conditions in the area also favor accumulation of pollution.

On some days, pollution levels in the Nashville area are very high. For example, on 5 percent of the days of the year, total particulate loadings exceed 320 micrograms per cubic meter (Figure 12).

In summary, the data clearly show that suspended particulate pollution in the Nashville area is excessive. Conditions are particularly bad in the fall and winter seasons and in the central parts of the urbanized area.

SOILING INDEX

Soiling index measurements were made by passing ambient air through filter paper and then determining the reduction in light transmission through the used filter paper as compared to unused filter paper. Results are expressed as Cohs (coefficient of haze) per 1,000 lineal feet of air. The measurement provides an approximate index of the ability of particles in the atmosphere to soil surfaces (e.g. windows, drapes, and buildings) and to reduce visibility through the atmosphere. A 24-hour sample was collected daily at 36 Type II and Type III stations, including the four semirural control stations. In addition, 2- and 4-hour samples were collected continually at 11 Type III stations, including the 4 control stations. The data are summarized in Figures 15, 16, 17, and 18 and Table 17.[34, 36, 37]

Seasonal variation in soiling index was very marked (Figure 16). Average values in the urban area ranged from almost 2.3 Cohs per 1,000 lineal feet in the winter to about 0.5 in the summer. December

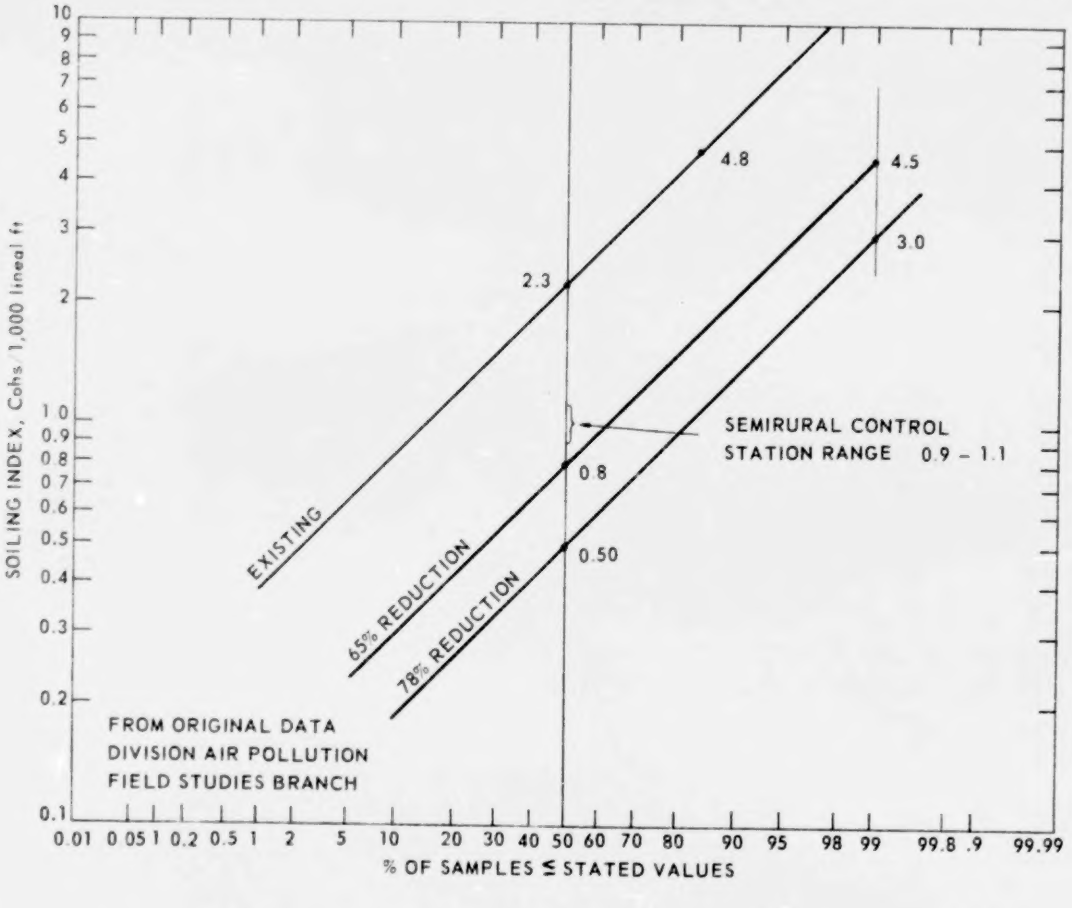


Figure 15. Two-hour soiling index cumulative frequency distribution, winter season, Dec., Jan., Feb. 1958-1959; seven stations, geometric mean.

Table 17. WINTER SEASON SOILING INDEX, AVERAGES OF 2-HOUR SAMPLES

Seven urban stations				Four semirural control stations			
Month	Geometric mean, Cohs/1,000 lineal ft	Geometric standard deviation	84th percentile, Cohs/1,000 lineal ft	Month	Geometric mean, Cohs/1,000 lineal ft	Geometric standard deviation	84th percentile, Cohs/1,000 lineal ft
Dec. 1958	2.54	1.98	5.00	Nov. 1958	0.76	2.21	1.68
Jan. 1959	2.28	2.24	5.11	Dec. 1958	1.12	1.78	1.99
Feb. 1959	1.98	2.14	4.25	Jan. 1959	0.98	1.97	1.93
Winter season	2.26	2.13	4.83	Feb. 1959	0.87	2.00	1.74
				Mar. 1959	0.49	2.86	1.40
				Apr. 1959	0.49	2.21	1.08
				May 1959	0.27	2.06	0.56

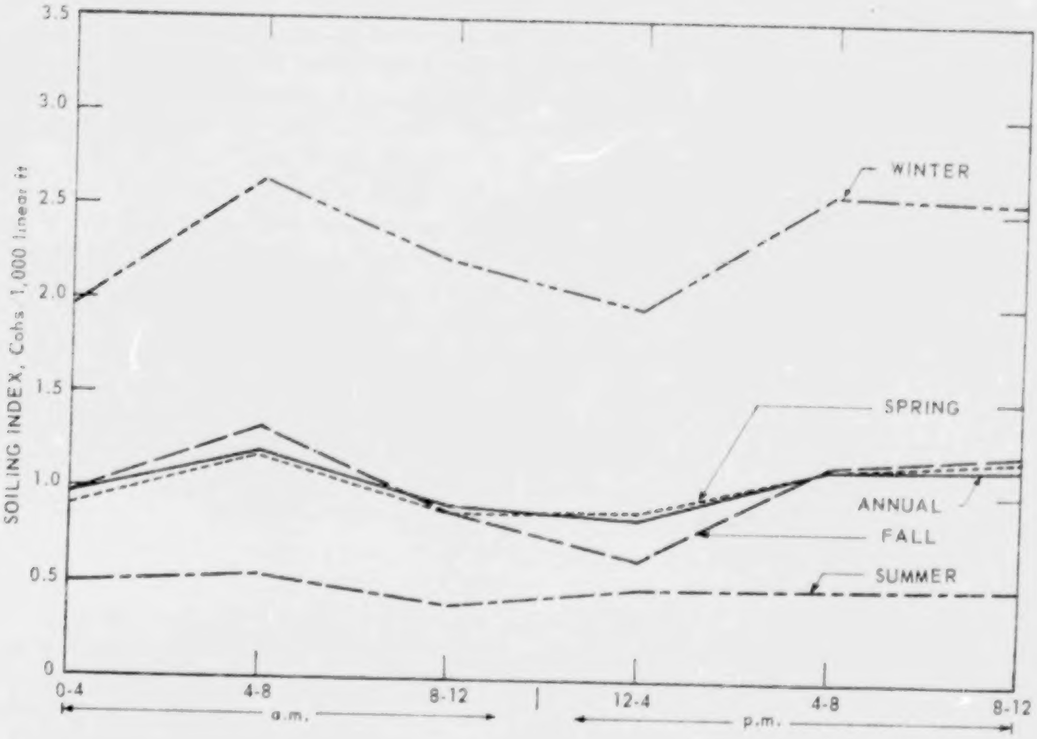


Figure 16. Four-hour soiling index determined by seven sampling stations (See Reference 36).

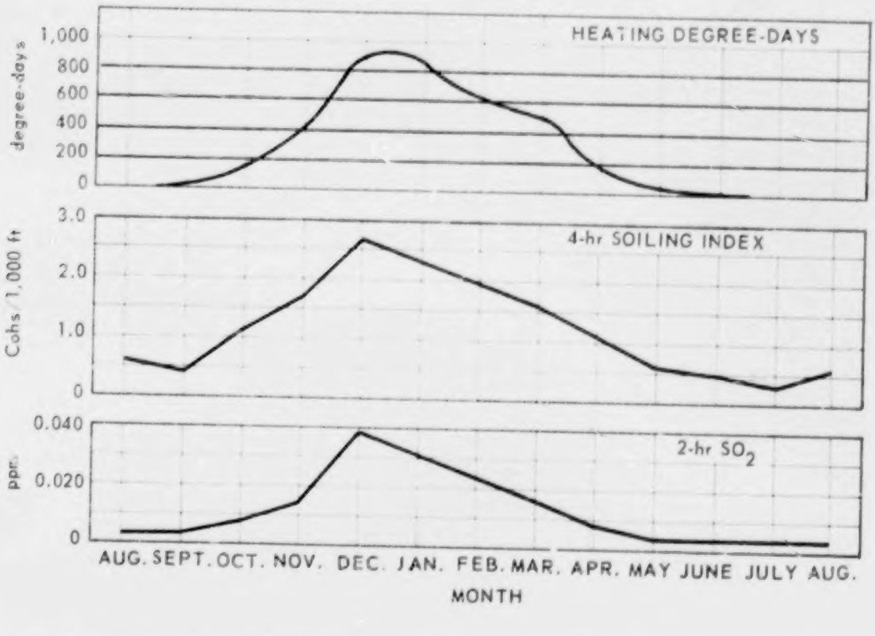


Figure 17. Heating degree-days and geometric mean monthly levels for soiling index and sulfur dioxide, 1958-59, at seven urban stations.

and January values were particularly high. This pattern reflects the increased emission of smoke and ash from space heating equipment, especially that which is coal-fired, during the colder months. This is borne out by the close resemblance of the heating degree-day curve, sulfur dioxide values, and the monthly average soiling index values (Figure 17).

Soiling index values at the semirural control stations demonstrate a monthly and seasonal variation similar to values observed in the urban area. This variation shows the influence of pollution arising in the urbanized area on locations about 3 miles beyond the urbanized area. Winter-month pollution levels at the control stations are four times some spring-month levels (Table 17). Since few sources of pollution are near the control stations, the increase is assumed to be due primarily to pollution carried out into the country from the urban area.

The State of New Jersey has developed a rating system for judging the severity of soiling in communities. Values from 2.0 to 2.9 Cohs per 1000 lineal feet are classified as "heavy soiling," and those from 3.0 to 3.9 as "very heavy soiling." [39] These ratings refer to the capacity of pollutants in the atmosphere to soil clothing, furnishings, buildings, etc. The number of people living in Nashville areas having various soiling index values for their atmosphere was determined on the basis of Figure 18 and population data. About 140,000 people live in areas where the wintertime soiling index is classified as heavy from 6 to 8 a.m., and about 88,000 people live in areas where the soiling is classified as very heavy at the same time.

Soiling index values in general are highest from 6 to 10 a.m. Since Figure 18 shows the 6 to 8 a.m. to be considerably higher than the midnight to 2 a.m., soiling index, Nashville is similar to other cities in this respect. The higher values from 6 to 8 a.m. are due to increased pollutant emissions as the people start their daily activities and to generally less favorable meteorological conditions for dispersion of pollution around 6 a.m. than at most other times.

The geographical area subjected to heavy soiling is much smaller in the spring than in the winter (Figure 18). Only a very small area in the central part of Nashville experiences 6 to 8 a.m. soiling values of 2.0 to 2.9 Cohs per 1,000 lineal feet in the spring season, a much cleaner situation than indicated by the winter season maps.

In summary, the data show that soiling is excessive in Nashville in the winter season. Soiling is not a serious problem in other seasons, although on a few days in the spring and fall, soiling is somewhat greater than desirable. The influence of soiling particles arising in the city and deposited at locations 3 miles beyond the urban area is significant. A major source of soiling particles is space heating equipment; coal-fired furnaces are the greatest contributors to this problem.

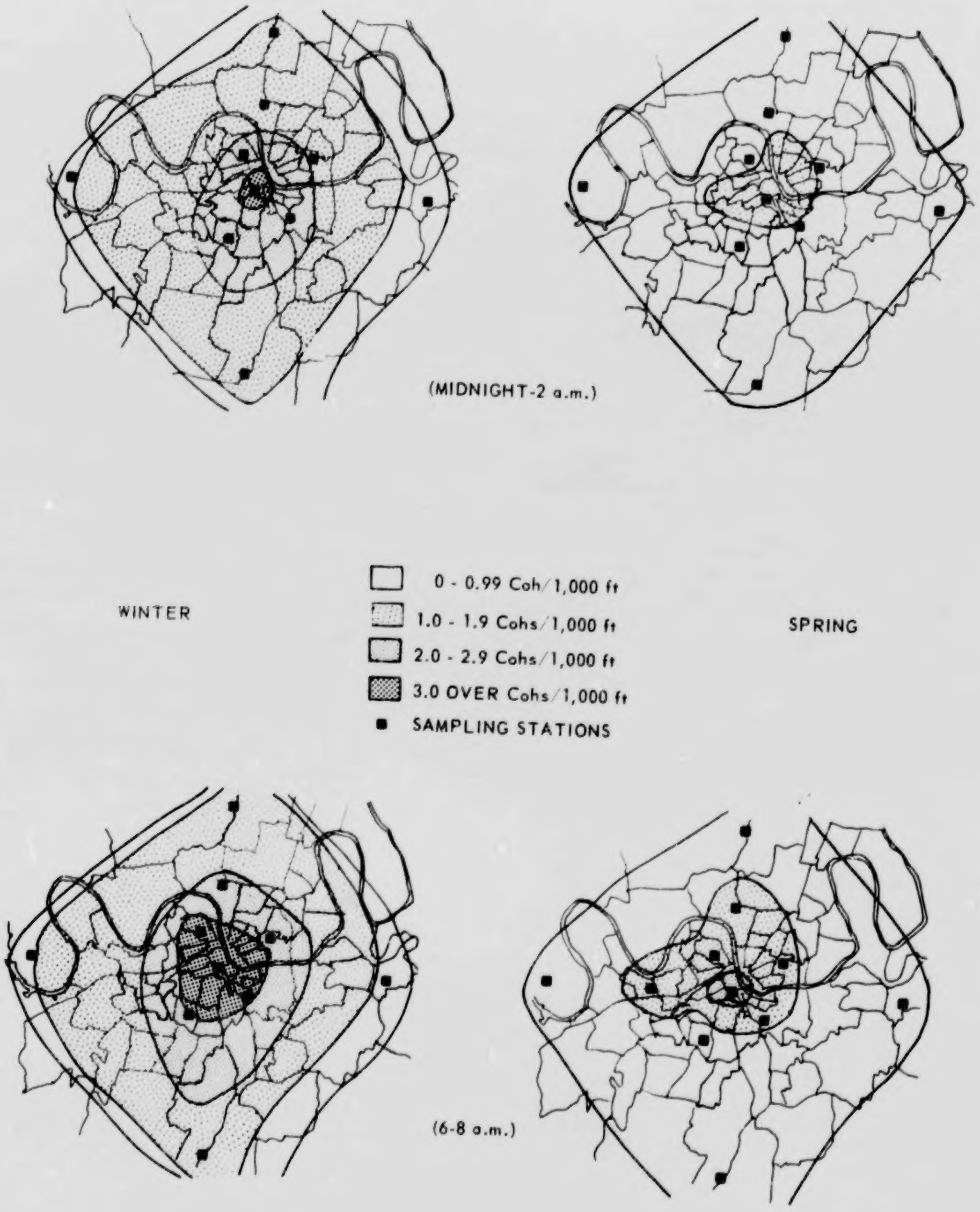

(MIDNIGHT-2 a.m.)
WINTER
SPRING
☐ 0 - 0.99 Coh/1,000 ft
▨ 1.0 - 1.9 Cohs/1,000 ft
☐ 2.0 - 2.9 Cohs/1,000 ft
▩ 3.0 OVER Cohs/1,000 ft
■ SAMPLING STATIONS
(6-8 a.m.)

Figure 18. Comparison of winter and spring geometric mean soiling distributions, selected 2-hour periods (See Reference 38).

SULFUR DIOXIDE

During the 1-year survey, approximately 12,000 twenty-four-hour samples and 30,000 two-hour samples of atmospheric sulfur dioxide were collected and analyzed with a slightly modified tetrachloromercurate (TCM) procedure originally described by West and Gaeke.[40,41] This method is very sensitive and quite specific for sulfur dioxide although presence of ozone and nitrogen dioxide in the air being sampled is thought to cause erroneously low results. The low indicated concentrations may also have been caused in part by the sampled air being passed through a filter paper before entering the sulfur dioxide absorber.

A Thomas Autometer was used to measure sulfur dioxide continuously at station 60 (the central station). The Thomas Autometer is not specific for sulfur dioxide, but responds to any soluble gas that yields electrolytes in the collecting solution; therefore, some positive interference (increased values) in evaluating atmospheric sulfur dioxide may occur.[42] The total electrical conductivity of the absorbing solution is measured and recorded in terms of equivalent sulfur dioxide concentrations. Although it is not specific for sulfur dioxide, this instrument has been widely used for monitoring complex urban atmospheres.

Sulfur dioxide and other reactive sulfur compounds were also measured by the lead peroxide candle method at 123 sampling stations. Four of these stations were for control purposes. Lead peroxide paste was applied to gauze that had been wrapped around a glass jar. The prepared jars ("candles") were placed in shelters in the field, where they remained for 30 days. Sulfur dioxide as well as certain other sulfur compounds in the air react with the lead peroxide to form lead sulfate, which is measured by chemical analysis. Results are expressed as milligrams of sulfur trioxide (SO_3) per 100 square centimeters of lead peroxide surface per day (mg SO_3/100 cm^2/day). The results are summarized in Table 18 and Figure 19.

Table 18. ANNUAL AND SEASONAL GEOMETRIC MEAN SULFATION RATES[a] DETERMINED BY 119-URBAN-STATION NETWORK

	SO_3, mg/100 cm^2/day
Nashville 1958-1959	0.190
Fall	0.173
Winter	0.536
Spring	0.186
Summer	0.073

[a] Taken from Reference 32.

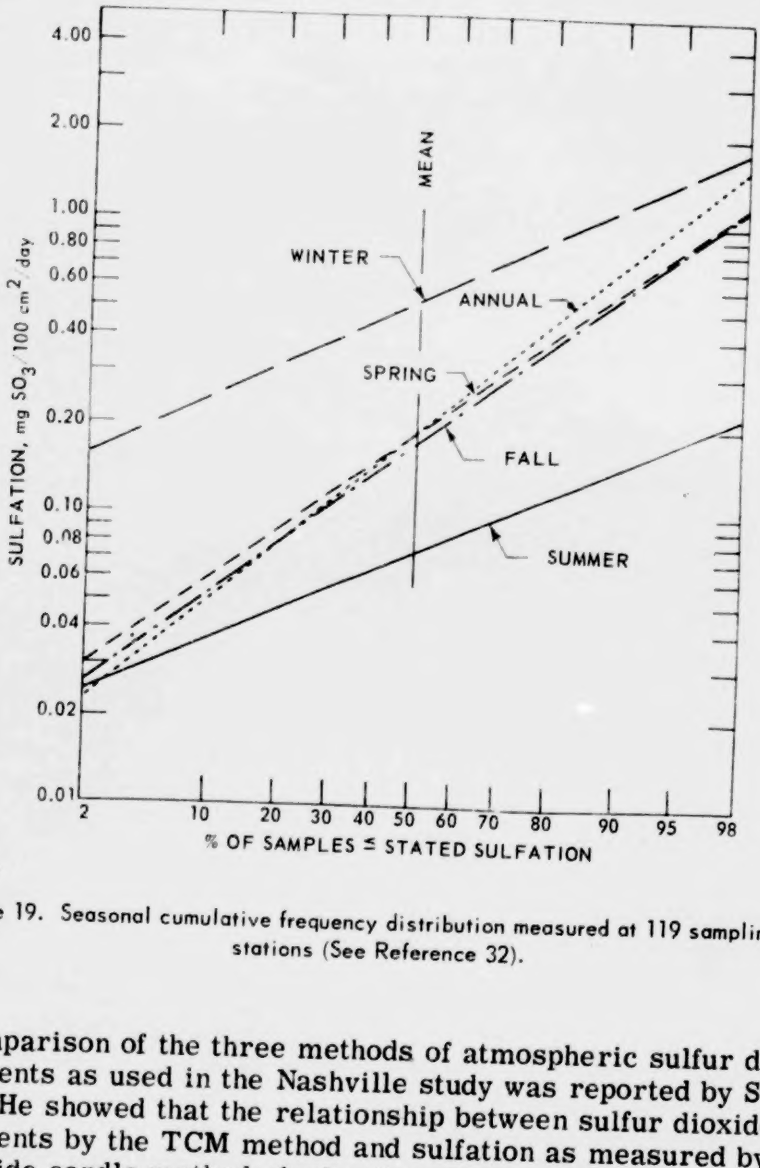


Figure 19. Seasonal cumulative frequency distribution measured at 119 sampling stations (See Reference 32).

A comparison of the three methods of atmospheric sulfur dioxide measurements as used in the Nashville study was reported by Stalker, et al. 41 He showed that the relationship between sulfur dioxide measurements by the TCM method and sulfation as measured by the lead peroxide candle method, during the winter season, was: 1 mg $SO_3/100\ cm^2/day \approx 0.042$ ppm SO_2 averaged over 2-hour periods.

The Thomas Autometer measurements of sulfur dioxide averaged over 2-hour periods were two to three times higher than the 2-hour TCM measurements and almost two times as high as the 24-hour TCM measurements. This causes difficulty in interpreting the data. Although it is probable that the TCM measurements more nearly indicate the true sulfur dioxide concentrations, it is possible that the actual values may be higher, as indicated by the Autometer measurements. There is no doubt that the differences actually occurred, but no adequate explanation is possible in the light of current information. One can only keep the matter in mind, do the best possible job of interpreting the data, and hope that further research will provide more useful information.

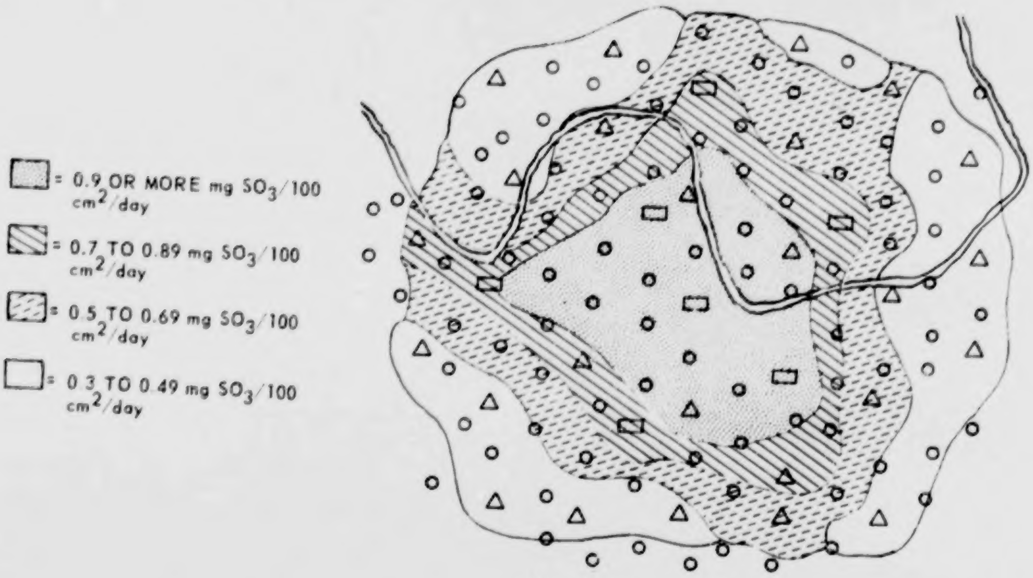
The geographic distribution of various sulfur dioxide pollution levels in the winter season as indicated by sulfation rates determined by the lead peroxide candle method and by the TCM method are shown in Figure 20.[32] There is good general agreement in results using the two methods. Highest sulfur dioxide levels prevail in the central part of the urbanized area. The number of people living in areas with various atmospheric sulfur dioxide levels as indicated by sulfation measurements was determined on the basis of Figure 20 and population statistics. About 120,000 people live in areas where winter season average sulfation rates exceeded 0.7 mg SO_3/100 cm^2/day. This level of sulfur dioxide pollution is undesirably high.

Sulfur dioxide may cause damage to certain species of vegetation if present at a concentration of 0.2 ppm or more for an 8-hour period or at 1.0 ppm for 1 hour. The frequency of occurrence of concentrations above 0.2 ppm (Figure 21) is, therefore, of interest. At station 48, about 5 percent of the 2-hour samples collected in the winter time exceeded 0.2 ppm, and at station 60, about 2.5 percent. At stations 19, 52, 82, and 90, about 1.5 to 2.0 percent of the samples exceeded 0.2 ppm. At four of the seven sampling stations, more than 10 percent of the 2-hour samples exceeded 0.1 ppm in the winter season, with station 48 experiencing this relatively high level about 24 percent of the time. Frequency of occurrence of concentrations above 0.1 and 0.2 ppm is greatest for the 6 to 8 a.m. period of the day and lowest for mid-afternoon hours (Figure 21).

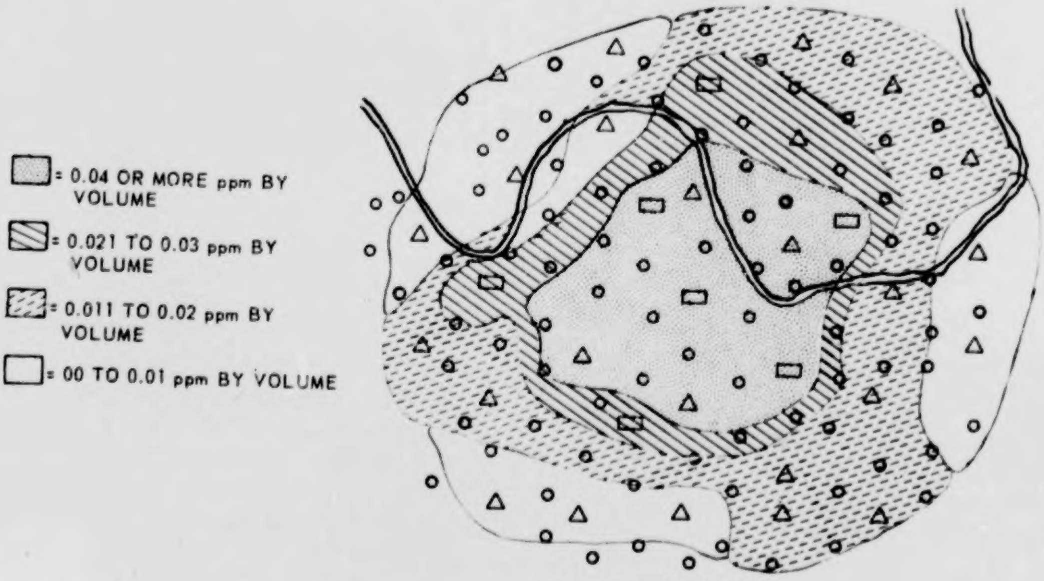
The months of November through March have the greatest frequency of occurrence of 2-hour sulfur dioxide concentrations greater than 0.1 and 0.2 ppm (Figure 21). These are the months when use of fuel for space heating is greatest; therefore, fuel-burning is implicated as a major contributor to atmospheric sulfur dioxide. The emission inventory confirms this reasoning and shows that coal-burning is the major source of sulfur dioxide. The data in Figure 21 indicate that sulfur dioxide is not a problem during the months of April through September.

On days when meteorological conditions are not favorable for dispersion of pollution and emission of pollutants is great, some very high concentrations of sulfur dioxide occur in Nashville. For example, 0.83 ppm occurred in a 2-hour sample at station 82 from 6 to 8 a.m. on Christmas Day of 1958. An instantaneous peak of 1.8 ppm was recorded by the Thomas Autometer at station 60 at about 10 a.m. on January 10, 1959. These were both maximums for the study period of 1958-59.

Continuous automatic recording instruments similar to the Thomas Autometer are operated by the Public Health Service in six cities. Several gases in addition to sulfur dioxide are measured in this project, which is referred to as the "Continuous Air Monitoring Program" (CAMP) (Figure 22). Sulfur dioxide concentrations from the recorder operated in Nashville from January to May 1959 indicate more of this pollutant than in any of the CAMP cities except Chicago. All of the

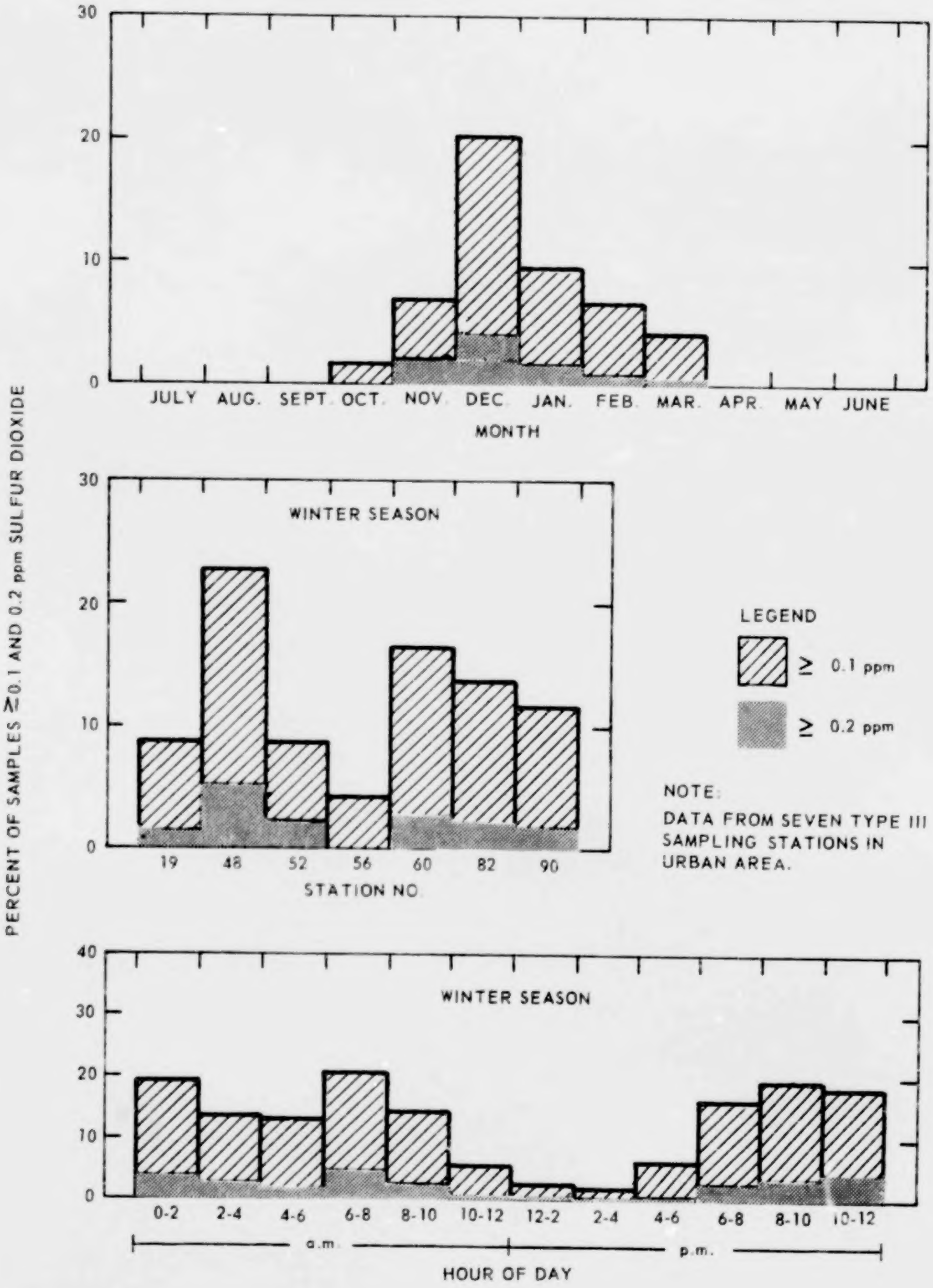

= 0.9 OR MORE mg SO_3/100 cm^2/day
= 0.7 TO 0.89 mg SO_3/100 cm^2/day
= 0.5 TO 0.69 mg SO_3/100 cm^2/day
= 0.3 TO 0.49 mg SO_3/100 cm^2/day

SULFATION RATES
(LEAD PEROXIDE CANDLE METHOD)


= 0.04 OR MORE ppm BY VOLUME
= 0.021 TO 0.03 ppm BY VOLUME
= 0.011 TO 0.02 ppm BY VOLUME
= 00 TO 0.01 ppm BY VOLUME

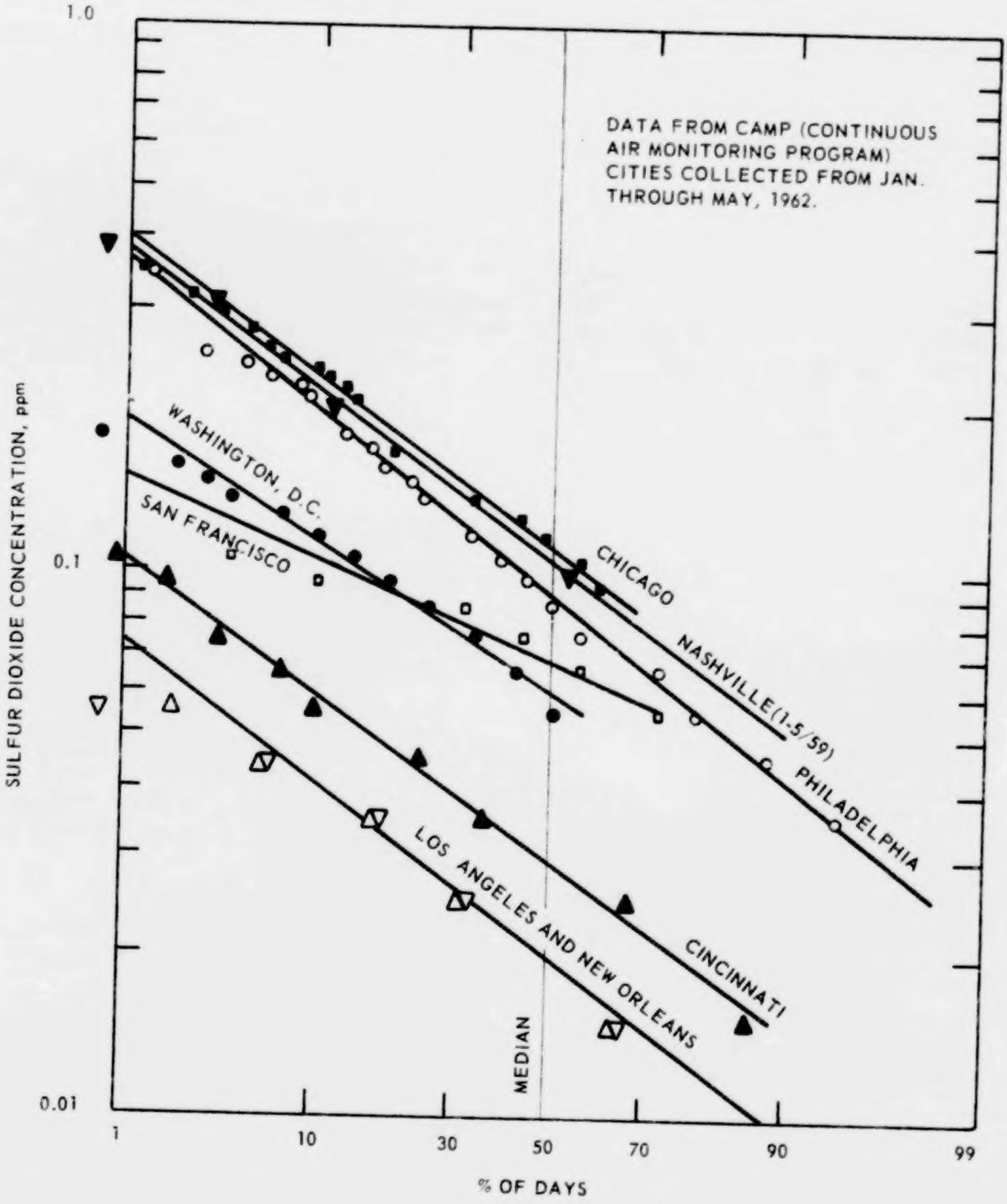
SULFUR DIOXIDE LEVELS
(TCM METHOD)

Figure 20. Comparison of sulfation rates and sulfur dioxide levels; data from 32 type II and type III sampling stations in urban area, winter season geometric means (See Reference 32).



NOTE:
DATA FROM SEVEN TYPE III SAMPLING STATIONS IN URBAN AREA.

Figure 21. Two-hour sulfur dioxide concentrations above 0.1 and 0.2 ppm (See Reference 37).



DATA FROM CAMP (CONTINUOUS AIR MONITORING PROGRAM) CITIES COLLECTED FROM JAN. THROUGH MAY, 1962.

Figure 22. Frequency of various 24-hour mean sulfur dioxide concentrations at CAMP stations and Nashville.

CAMP cities are considerably larger than Nashville, which indicates that Nashville, in addition to having high sulfur dioxide levels, has levels far above what it should have, for its size. This reflects the relatively high emission rates and poor meteorological and topographical conditions for dispersion of pollutants that exist in Nashville.

The levels of sulfur dioxide during disasters, in which many more than the usual number of people died, in London, England, Donora, Pa., and New York City, were in the same range as the maximum levels found in

Nashville.[43] The extremely high concentrations did not persist for so long a time in Nashville; however, there is cause for concern, but not for panic. Furthermore, sulfur dioxide, while present in abnormally high quantities during these disasters, is not considered to be the sole causative agent of the illnesses and deaths that occurred. Laboratory experiments indicate that other pollutants also play a role in causing the acute effects experienced by people. Bronchial-asthma attack rates, total morbidity, cardiovascular morbidity, and respiratory disease mortality, with certain exceptions, are, however, significantly higher in Nashville, where exposure to sulfur dioxide and particulates as measured by the soiling index are greater. (See Effects section.)

In summary, the data indicate that sulfur dioxide concentrations in the Nashville area are excessive during the winter space-heating season.

OXIDANTS

Oxidants, as considered here, are those substances in the atmosphere capable of reacting with potassium iodide to release free iodine. A principal oxidant constituent is ozone, with lesser amounts of alkyl peroxides, nitrogen dioxide, and several other compounds usually present. The oxidant complex is not characteristic of emissions from particular sources as such, but is the result of photochemical reactions among atmospheric contaminants (especially hydrocarbons and nitrogen oxides) in the presence of sunlight.

The State of California in its standards for ambient air quality, established the "adverse" level for oxidants at 0.15 ppm for 1 hour, as determined by the potassium iodide method. It is the level at which eye irritation, plant damage, and visibility reduction may be experienced.[44]

Oxidants were measured in Nashville at station 60 in the 1958-1959 study with a continuous recording instrument. Operation of the instrument is based on a colorimetric analysis using the buffered potassium iodide reaction. The concentrations were recorded as peaks and averages within one-half-hour periods. The data for October 1958 through April 1959 are shown in Figure 23. The highest recorded momentary concentrations were 0.16 ppm, which occurred on October 6, 20, and 21; November 11, 13, and 21; and April 16. The 1/2-hour average at the time of these peak periods was generally around 0.13 ppm. The meteorological conditions on these days were generally low wind speed, clear skies, and a 24-hour temperature span of approximately 30°F. These parameters suggest that a radiation-type inversion existed. The typical photochemical smog symptoms of Los Angeles occur most frequently with similar meteorological conditions.

Oxidant values in cities similar to Nashville with respect to air pollution are generally greatest during the summer months. No

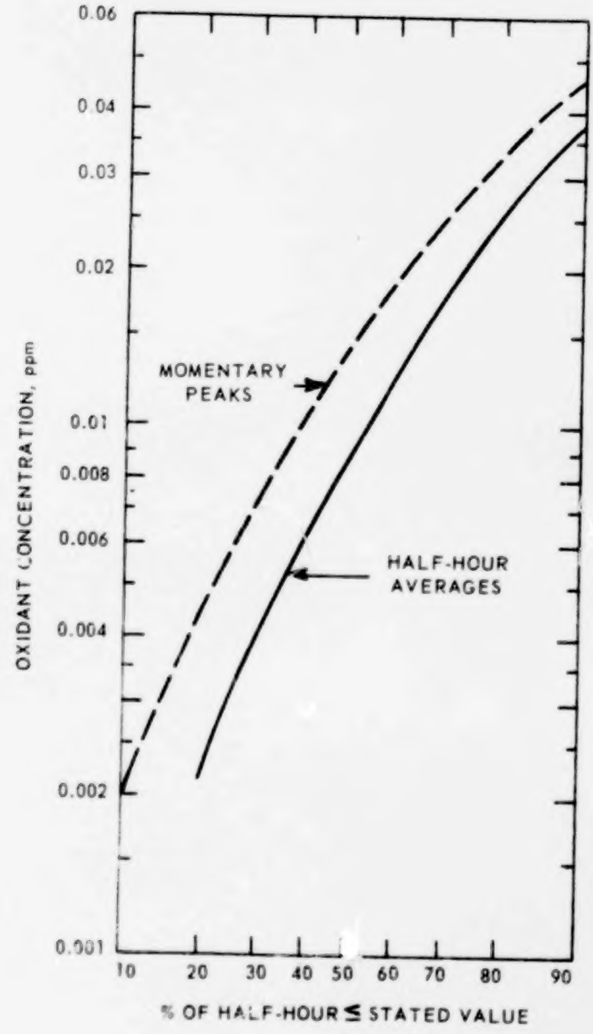


Figure 23. Frequency distribution of oxidant peak and of average concentrations, October 1958 - April 1959.

measurements were made during the summer in Nashville; therefore it must be inferred that the highest concentrations have not been measured as yet.

The fact that "adverse" levels of oxidants have been approached in Nashville indicates the need for a monitoring program for this pollutant with followup measures as indicated by the results of monitoring and observed effects such as eye irritation and vegetation damage.

AEROALLERGENS

Reports concerning the aeroallergen investigation made during the 1958-1959 study have not been prepared. This very important subject is worthy of future supplementary work. Such studies would not alter the program development considerations presented in this report.

Nashville is situated in an area of the country where pollens are plentiful. In regard to ragweed pollen, the condition is well stated in a 1961 publication[45] of the American Academy of Allergy: "Tennessee; no refuge areas are known. Along the crest of the Great Smoky Mountains at Newfound Gap, conditions were found to be good. There are no accommodations at this point, but there might be places with similar conditions at similar or higher elevations."

CARCINOGENS

One of the components of particulate matter in the air over cities is the polynuclear hydrocarbon, benzo(a)pyrene, hereafter referred to as BaP.

BaP is important because of its demonstrated ability to produce cancer in laboratory animals and its suspected ability to cause cancer in man. A constituent of tars, it comes from the destructive distillation or incomplete combustion of carbonaceous materials, including coal, oil, refuse, and gasoline. It exists in the atmosphere in the solid state and, therefore, is collected with other particulates. BaP is only one of many potential cancer-producing substances in the atmosphere.

The BaP content of the air over Nashville and other cities is reported in a paper by E. Sawicki, et al.[46] A summary of that paper follows: "Examination of the BaP content in the air of 131 urban and non-urban areas in various parts of the country has disclosed that BaP is universally present. Samples from sites in urban areas yielded higher concentrations of BaP in the air and in airborne particulates than those from nonurban areas. The concentration of BaP at these sites was found to vary from 0.01 to 61 micrograms per 1,000 cubic meters of air. A 12-month study of the atmospheric BaP concentration in nine large, widely separated American cities has shown that, for the majority the concentration of BaP in airborne particulates and in the air is at the highest level during the winter months and at the lowest level during the summer months. A map of the different concentrations of BaP found in the air shows a geographic variation which needs a more thorough study. The lower concentration of BaP in the particulates and in the air of California communities may be attributed to less winter heating, use of liquid and gaseous fuels, and in addition, may be due to the action of California sunshine and oxidizing atmosphere.

"The concentration of BaP in the benzene-soluble fractions of particulates from the air of different urban and nonurban areas varied from 0.00093 to 0.26 percent. The concentration of BaP in the airborne particulates of urban and nonurban areas varied from 0.00001 to 0.041 percent. In cigarette tar the concentration of BaP is in the range of 0.00002 to 0.0001 percent.[47, 48]

"If annual inhalation of BaP may be considered a measure of lung cancer exposure, this exposure is about 100 times greater for an urban resident than a nonurban one, and the exposure is greater for a nonsmoker in many large American cities than for a pack-a-day smoker in a nonurban American community. In many American cities the exposure to BaP of the urban dweller who smokes a pack a day is double that of the non-smoking resident."

Table 19 indicates that the air over Nashville exposes a person to as much BaP as does the smoking of two packs of cigarettes per day. It also indicates that of the American cities studied, Nashville had next to the highest level of that pollutant.

Table 19. BENZO(a)PYRENE INHALED PER YEAR FROM AMBIENT AIR AND FROM SMOKING - CALCULATED FROM MEAN ANNUAL CONCENTRATION IN VARIOUS CITIES[a]

Sampling sites	BaP[b], µg/yr
Missouri State Forest	0.1
Helena, Montana	0.8
San Francisco, California	14
Los Angeles, California	20
New Orleans, Louisiana	26
Atlanta, Georgia	44
Cigarette smoke, pack a day	60
Cincinnati, Ohio	79
Detroit, Michigan	110
Nashville, Tennessee	120
Birmingham, Alabama	150
London (County Hall), England	320

[a] Taken from Reference 46.

[b] Benzo(a)pyrene.

Table 20, based on data from Sawicki's paper,[46] is presented to illustrate further the relationship of BaP concentrations in Nashville to other American cities. The number entries indicate the position of Nashville in relation to other cities. The entry "1st" indicates that Nashville had the highest concentration of BaP and "9th" the lowest concentration for the month. There is a tendency to find much larger amounts of BaP in the atmosphere of Nashville in the fall and winter seasons. This tendency appeared in most of the nine cities that were studied, but was so pronounced in Nashville as to place it at the highest or next to the highest level during those seasons. (No data were available for August, February, and March.) These data indicate that a substantial part of the BaP in Nashville's air comes from space-heating activities. The most likely source is small and inefficient coal-burning furnaces.

Table 20. COMPARISON OF BENZO(a)PYRENE CONCENTRATION IN NASHVILLE TO EIGHT OTHER CITIES[a]

Month	Year	Rating of Nashville in relation to 8 other cities[b]
July	1958	7th
August	1958	No data
September	1958	2nd
October	1958	1st
November	1958	1st
December	1958	2nd
January	1959	2nd
February	1959	No data
March	1959	No data
April	1959	3rd
May	1959	4th or 5th[c]
June	1959	6th or 7th[c]

[a] Taken from Reference 46.

[b] 1st indicates highest level of benzo(a)pyrene.

[c] Two cities with same values.

Another study by Eugene Sawicki, et al. was extended to seven hydrocarbons: anthanthrene, coronene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, perylene, and pyrene. In studies of carcinogenicity benzo(a)pyrene and benzo(g,h,i)perylene have demonstrated certain cancer causing activity in animals, while BaP has generally been rated strongly carcinogenic.[49] The atmospheric concentration of these polynuclear hydrocarbons for 12 cities is given in Table 21. In January 1959, the total concentration of the eight hydrocarbons analyzed in the Nashville air was 111.8 micrograms per 1,000 cubic meters. In comparison, the July 1958 concentration was 9.15 micrograms per 1,000 cubic meters. Of the cities studied, these levels place Nashville as having the third from highest winter concentration, dropping to third from lowest in the summer. This variation in seasonal concentration further demonstrates the tremendous influence of coal combustion for space heating on air quality in Nashville.

Table 21. POLYCYCLIC HYDROCARBON CONTENT OF AIR FOR SELECTED CITIES[a]

City	Month	Hydrocarbon[b], μg/1,000 m^3									Position
		BghiP	BaP	BeP	BkF	P	Cor	Per	Anth	Total	
Winter 1959											
Atlanta	Feb.	8.9	7.4	4.7	6.0	6.0	4.3	1.1	0.52	38.92	9
Birmingham	Feb.	18	25	10	13	17	3.5	5.5	2.2	94.2	4
Detroit	Feb.	33	31	23	20	25	6.4	6.0	2.0	146.4	1
Los Angeles	Feb.	18	5.3	8.1	5.7	6.0	12	1.6	0.16	56.86	7
Nashville	Jan.	17	25	14	15	30	4.6	4.4	1.8	111.8	3
New Orleans	Feb.	7.3	4.1	6.4	3.9	2.3	27	0.8	0.10	27.6	10
San Francisco	Jan.	7.5	2.3	2.9	1.7	1.9	4.9	0.34	0.10	21.64	12
Seattle	Jan.-Mar.	14	9.0	-	8.1	6.7	15	2.4	1.0	56.2	8
Sioux Falls	Jan.-Mar.	8.3	4.0	-	2.7	4.0	3.7	0.82	0.22	23.74	11
South Bend	Jan.-Mar.	12	16	14	10	32	4.7	3.0	1.5	93.2	5
Wheeling	Jan.-Mar.	14	21	-	13	22	3.8	2.6	1.4	77.8	6
Youngstown	Jan.-Mar.	22	28	-	18	34	3.4	7.4	3.4	116.2	2
Summer 1958											
Atlanta	July	5.1	1.6	1.5	1.3	0.73	2.5	0.40	0.2	13.3	6
Birmingham	July	8.3	6.4	5.9	4.6	2.1	2.4	2.1	0.25	32.05	2
Detroit	July	9.5	6.0	5.3	4.9	2.8	1.8	1.7	0.38	32.38	1
Los Angeles	July	2.3	0.5	0.63	0.45	0.27	2.2	0.034	0.03	6.41	8
Nashville	July	3.4	1.4	1.2	1.0	0.58	1.3	0.21	0.06	9.15	7
New Orleans	July	4.6	2.0	3.1	1.8	0.34	2.5	0.39	0.1	14.8	5
San Francisco	July	2.6	0.25	0.54	0.24	0.09	1.6	0.043	0.022	5.39	9
Cincinnati	July	6.0	3.9	4.0	3.5	1.7	2.8	0.93	0.07	22.9	3
Philadelphia	May	6.8	3.4	2.5	2.5	2.2	2.9	0.78	0.12	21.2	4

[a] Taken from Reference 49.

[b] BghiP=Benzo (g,h,i)perylene, BaP=Benzo(a)pyrene, BeP=Benzo(e)pyrene, BkF=Benzo(k)fluoranthene, P=Pyrene, Cor=Coronene, Per=Perylene, Anth=Anthanthrene.

[c] Number indicates position in relation to other cities for total polycyclic hydrocarbons measured; 1 indicates highest and 12, lowest.

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DISPERSION OF AIR POLLUTANTS

The rate at which air pollutants are dispersed in the atmosphere is governed by meteorological conditions and is influenced by topography. Two meteorological factors of prime importance are wind speed and vertical temperature gradient. As wind speeds increase, dispersion of pollutants is more rapid and generally lower pollution levels result. Vertical temperature gradients influence the depth of the layer of the atmosphere in which pollutants are dispersed and the rate at which pollutants are dispersed within a layer. Normally, the air near the ground is warmer than air at higher levels. The warmer air is lighter than the colder air and tends to rise. This sets up vertical air currents, which disperse pollutants through a relatively deep layer of air and lower the pollution concentrations. Sometimes, however, the air near the ground is cooler than the air at higher levels. When this occurs, a temperature inversion is said to exist. The cooler air is heavier than the warmer air above and tends to stay near ground level. Thus, vertical mixing is minimized and pollutants tend to accumulate and cause high pollution levels in the layer of air near the ground. The most common form of atmospheric temperature inversion is a nocturnal or radiation inversion, which occurs frequently during night and early morning hours with clear skies and light winds. Another type of inversion occurs when warm air masses from aloft descend in a layer to confine a layer of cooler air closer to the ground. This condition, in effect, puts a lid over an area and restricts the vertical dispersion of pollutants. This kind of inversion forms as the result of broad-scale weather patterns.

WIND SPEEDS

Wind speeds and calm periods influence the buildup of air pollution. Table 22 defines these conditions both in terms of percent of time and hours for the year in which the study took place. Wind speeds during the year of the study averaged 5.8 mph in summer, 6.4 mph in fall, 8.6 mph in winter, and 8.9 mph in spring. These differences are not so great as those in the Mississippi Valley or plains areas of the country. They do, however, help define certain influences. For example, the winds of higher average speeds during the winter heating season help disperse air pollution. The winds with low average speeds and the high percent of calm periods of the summer extend through October. This helps explain the severe buildups of air pollution that are observed in the fall months.

Table 22. WIND SPEEDS AND PERCENT OCCURRENCE, AUGUST 1958 TO AUGUST 1959

Year	Month	Avg wind speed mph	Calms, %	Calms, hr	0-3 mph, %	0-3 mph, hr	4-7 mph, %	4-7 mph, hr	8-12 mph, %	8-12 mph, hr	12 mph, %	12 mph, hr	Total hr
1958	Aug.	5.3	10.1	75	23.2	173	43.4	323	19.5	145	3.8	28	744
1958	Sept.	5.9	10.3	74	20.5	148	36.5	263	27.0	194	5.7	41	720
1958	Oct.	5.5	11.1	83	28.0	208	29.8	222	24.5	182	6.6	49	744
1958	Nov.	7.8	7.6	55	10.1	73	33.9	244	31.3	225	17.3	123	720
1958	Dec.	7.6	5.5	41	10.9	81	32.4	241	38.4	286	12.8	95	744
1959	Jan.	9.5	3.0	22	14.6	109	24.5	182	28.2	210	29.7	221	744
1959	Feb.	8.8	7.0	47	11.9	80	23.2	156	31.6	212	26.3	177	672
1959	Mar.	10.1	3.0	22	8.3	62	26.3	196	29.6	220	32.8	244	744
1959	Apr.	9.4	4.0	29	5.9	43	24.3	175	39.1	282	26.7	191	720
1959	May	7.3	7.8	57	14.5	108	32.3	241	31.0	231	14.4	107	744
1959	June	6.7	10.7	77	14.9	107	33.8	243	30.5	220	10.1	73	720
1959	July	5.5	14.7	109	18.3	136	39.6	295	22.4	167	5.0	37	744
Avg or total		7.4	7.9	691	15.2	1328	31.7	2781	29.4	2574	15.8	1386	8760

Wind speed and direction in small parts of the region around Nashville are influenced by topographic features of the area. The topography modifies general wind patterns, which are governed by broad area meteorological conditions. Ralph H. Fredrick of the Office of Climatology of the U.S. Weather Bureau has explained the situation as follows.[50] "Lines of equal monthly average 24-hour wind movement over Nashville show a relatively consistent pattern from month to month. This pattern consists of (1) a zone of strongest wind in the southeastern portion of the city, (2) a medium speed zone along the northern edge and in the northwestern sections, and (3) the least wind in an elongated zone stretching from southwest toward northeast (Figure 24). Close inspection of topographical conditions and prevailing wind shows a logical pattern of zones as described below:

"Zone 1. The southern border of the urban area shows an abrupt topographic change with high hills in its western half and relatively open area in the eastern half. Also, the prevailing wind for Nashville is from a southerly direction; therefore, as might be expected, the southeastern section of the urban area experiences the highest monthly average wind speed.

"Zone 2. The hills northwest of the city are 700 to 800 feet above mean sea level. The secondary wind frequency maximum for Nashville is northwesterly and the average speed of northwesterly winds is greater than that from other directions. While the hills are high enough to distort the wind pattern, they do not exert as much influence upon the wind field as do the higher and more massive hills southwest of the city. However, this hill influence upon northwesterly winds and the drag which the uneven urban area exerts upon southerly winds, combine to make the northwest portion and north central border areas, the medium speed wind zone labeled Zone 2.

"Zone 3. The high hills south-southwest and southwest of the city provide the southwest portion of the city with a barrier to the prevailing wind flow. The southwestern quadrant of town is also protected from westerly winds by lesser hills to the west of the city and from northerly winds by the long trajectory over the urban area. The center of Nashville is the lowest elevation in the urban area and has the greatest concentration of uneven building heights. The northeastern section of the city is low in wind speed because of the long urban trajectories of winds from all frequent directions and because elevations in this area are also quite low. The three areas mentioned combine to form an elongated SW-NE zone of low wind speed designated as Zone 3."

Zone 3, where low wind speeds occur, includes the central part of the urbanized area. The low wind speeds and the location of pollution sources contribute to the highest pollution levels occurring in the central area rather than in other areas. The foregoing information is of importance in planning the location of operations that will be new pollution sources and in general management of the air resource of the area.

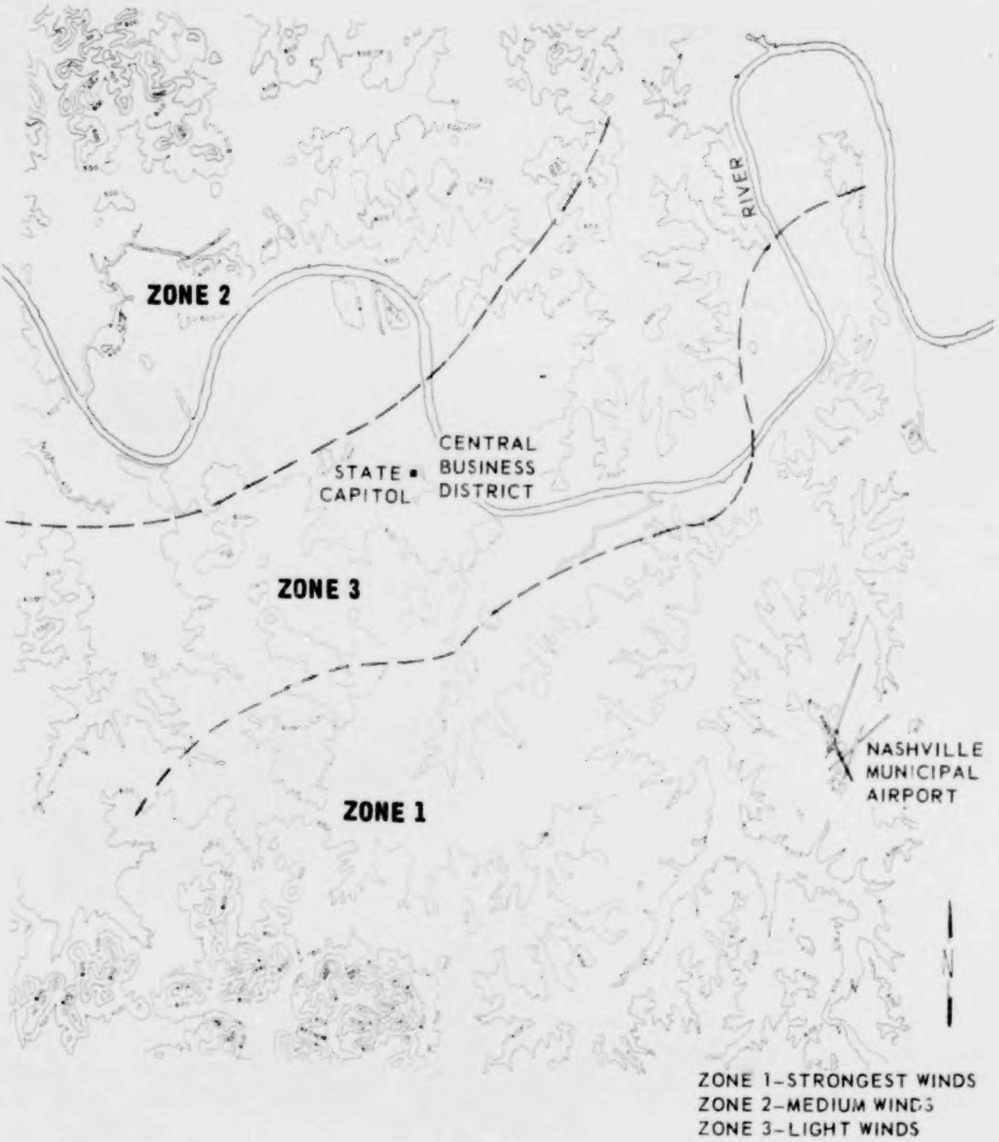

ZONE 2
RIVER
STATE CAPITOL
CENTRAL BUSINESS DISTRICT
ZONE 3
NASHVILLE MUNICIPAL AIRPORT
ZONE 1
N
ZONE 1–STRONGEST WINDS
ZONE 2–MEDIUM WINDS
ZONE 3–LIGHT WINDS

Figure 24. Surface wind zones on a contour map of Nashville region.

Wind direction determines the area that will be influenced by a particular source or a group of sources of pollution. South and south-southeast winds predominate, with northwesterly winds being next most common (Figure 25).

VERTICAL TEMPERATURE GRADIENTS

The total frequency of atmospheric temperature inversions in the Nashville area ranges from 30 to 40 percent of the total hours for various seasons of the year (Figure 26). 51 This frequency is in the middle to high part of the range of values reported for various parts of the nation. These data indicate that moderately poor conditions for dispersion of pollution exist in Nashville as compared to other parts of the country.

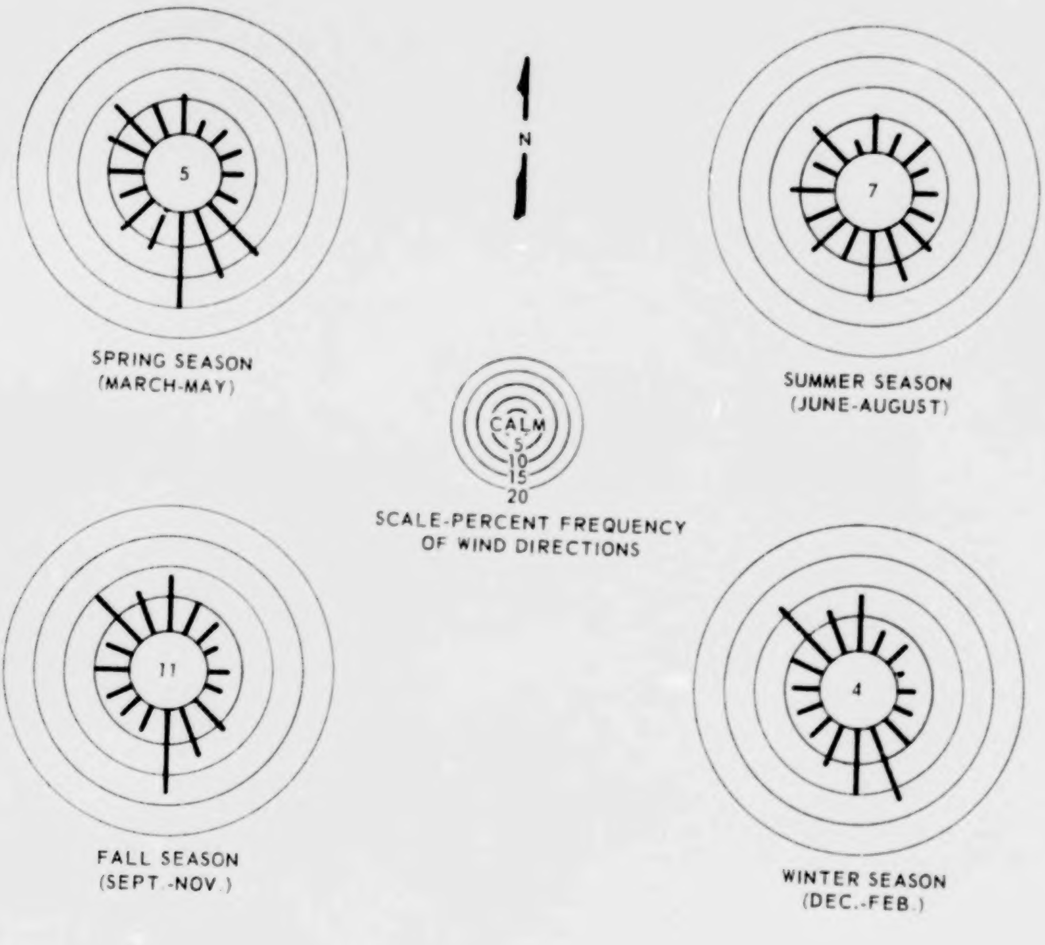
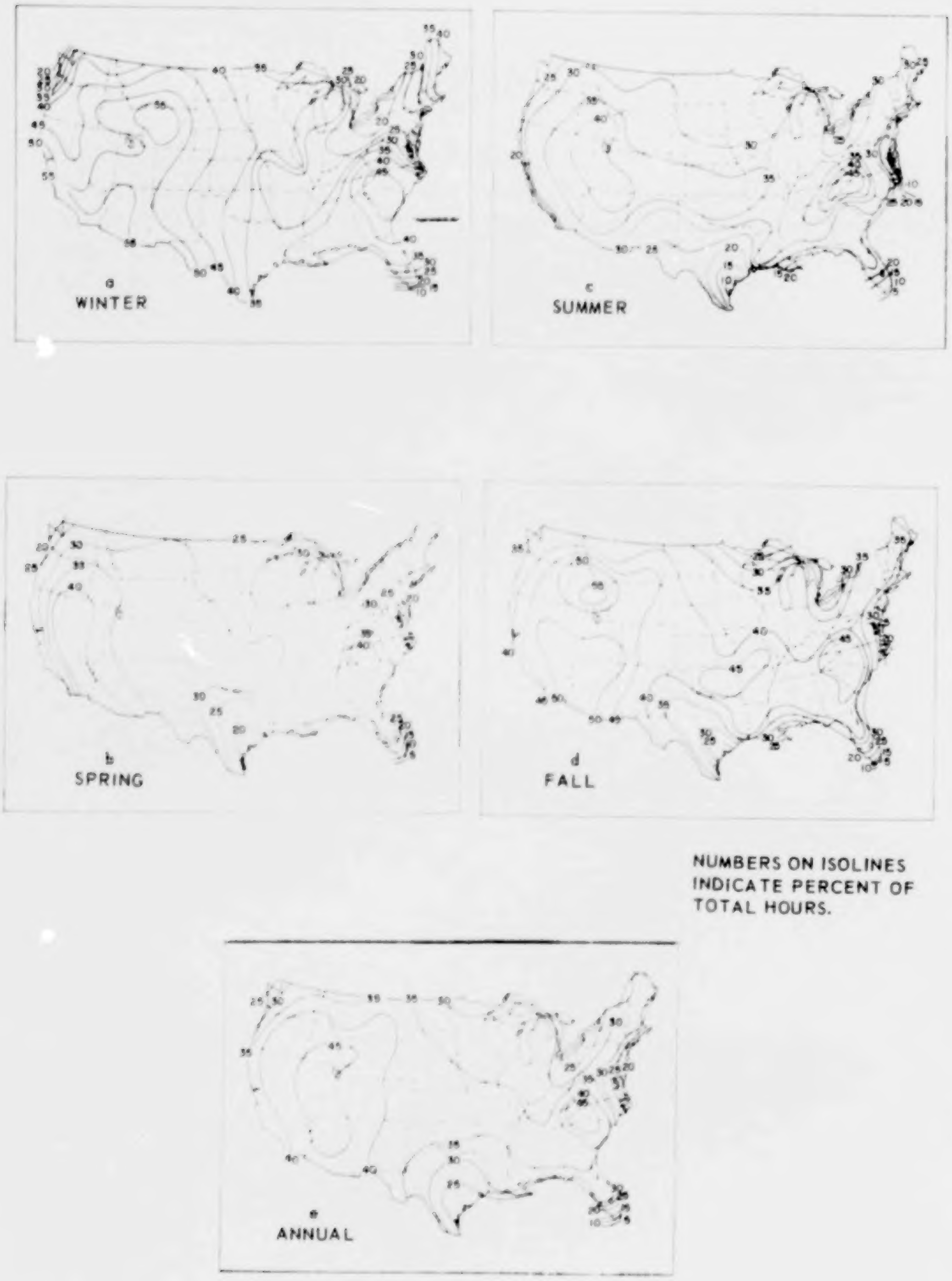


Figure 25. Wind roses for Nashville from data taken at airport, 1949 - 1954.


a
WINTER
c
SUMMER
b
SPRING
d
FALL
e
ANNUAL

NUMBERS ON ISOLINES INDICATE PERCENT OF TOTAL HOURS.

Figure 26. Inversion frequency (See Reference 51).

Korshover has tabulated the frequency of occurrence of atmospheric stagnation cases lasting 4 or more and 7 or more days.[52] These are periods when unusually high pollution levels would be expected. The Nashville area experienced about 31 stagnation cases lasting 4 or more days with a total of about 146 stagnation days during the 21-year period 1936-1956 (Figure 27). This is among the highest occurring in the area east of the Rocky Mountains and indicates that the Nashville area has relatively frequent stagnation conditions, which result in unusually high pollution levels. About two such prolonged stagnation periods would be expected annually.

Stagnation periods lasting 7 or more days occur about once every 10 years in the Nashville area (Figure 28). During these periods, extreme pollution levels would be expected. Again the Nashville area is in an unfavorable situation compared to other areas.

Stagnation conditions lasting 4 or more days occur most frequently in the months of June, August, September, October, and November (Table 23). This agrees with the percent of calms indicated in the center of the composite wind roses shown in Figure 25.

The suspended particulate levels as measured by Hi-Vol samplers are highest in the fall, when calms are most prevalent. The sulfur

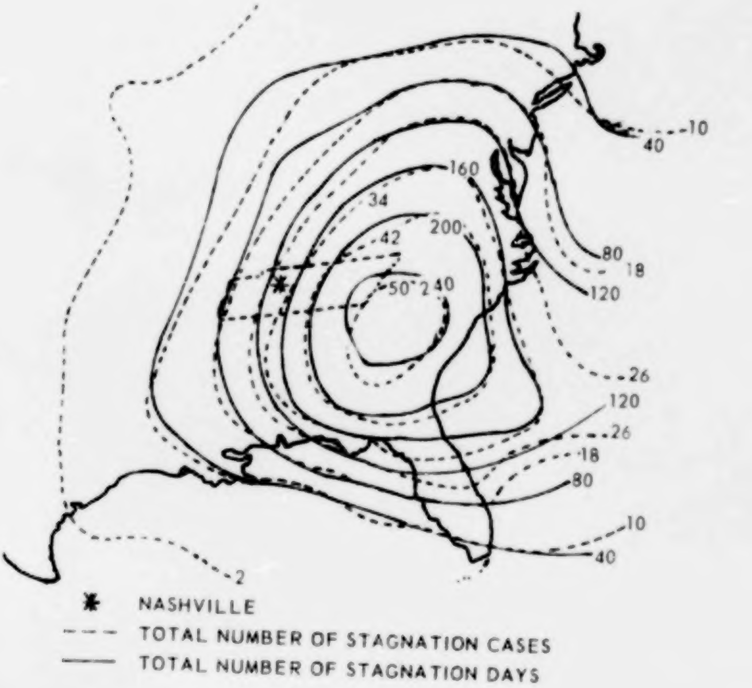
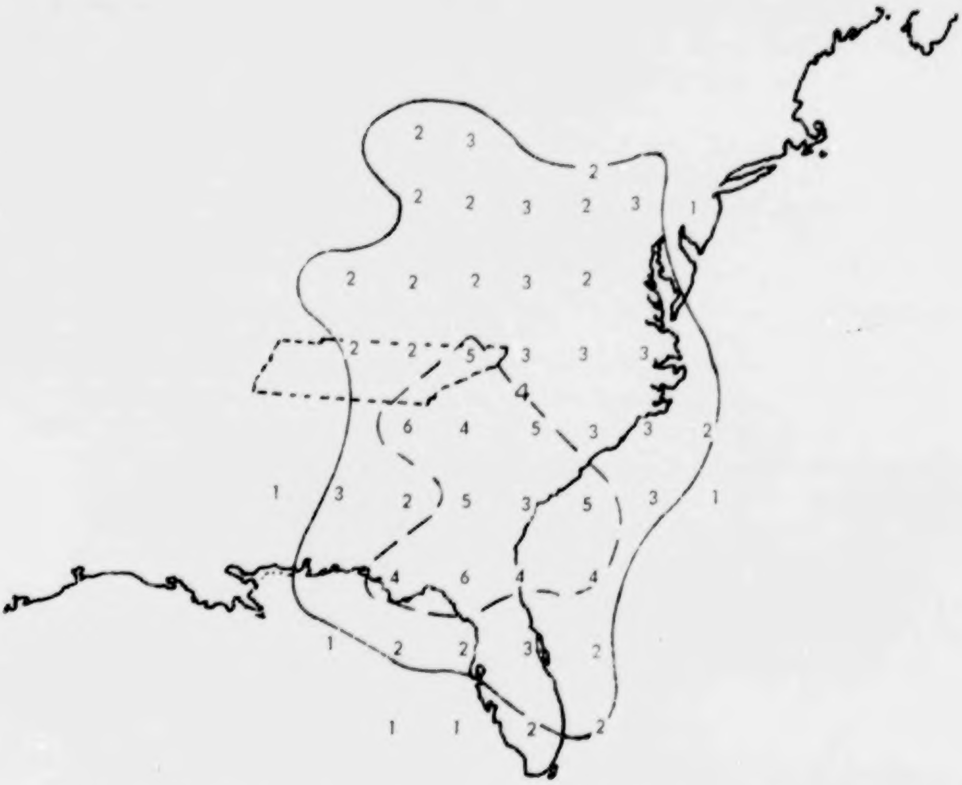

10
40
160
34
200
42
50
240
80
18
120
26
120
26
18
80
10
40
2
NASHVILLE
TOTAL NUMBER OF STAGNATION CASES
TOTAL NUMBER OF STAGNATION DAYS

Figure 27. Occurrence of atmospheric stagnation of 4 or more days duration 1936 - 1956 (See Reference 52).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2

Figure 28. Total number of stagnation cases of 7 or more days duration from 1936 - 1956 (See Reference 52).

Table 23. MONTHLY FREQUENCY OF ATMOSPHERIC STAGNATION CASES OF 4 DAYS OR MORE IN NASHVILLE AREA, 1936 - 1956[a]

Month	Stagnation cases
January	0
February	0
March	0
April	1
May	2
June	5
July	0
August	4
September	4
October	11
November	4
December	0
Total	31

[a] Taken from Reference 52.

dioxide and soiling values do not reflect the influence of meteorological conditions as much as they do the emissions of this pollutant due to use of fuel for space heating.

TEMPERATURE

Another meteorological factor that has an indirect effect on air pollution levels is temperature since more fuel must be burned for space heating in colder weather. A measure of space heating and fuel use requirements is the degree-day. This is the difference between the average temperature for a day and 65°F. If average temperatures for a day were 45, the day would be assigned a value of 65 minus 45 or 20 degree-days.

In summary, the data available indicate that meteorological and topographical features of the Nashville area are conducive to the build-up of air pollutants.

EFFECTS OF AIR POLLUTION

GENERAL DISCUSSION

Acute air pollution episodes have caused illness and death.[53] Considerable information is available concerning conditions that existed during these tragic occurrences. Information concerning possible chronic effects, however, is far from adequate although there is an impressive body of circumstantial evidence that points toward the detrimental results of long-term, low-level exposure to air pollutants. Some of this evidence has resulted from studies in Nashville.

Aside from consideration of health effects, air pollution costs the people of the United States an estimated $7.5 to $11 billion annually because of corroded metals; damage to buildings, crops, soil, and livestock; lowered real estate values; and added costs to industry.[54] It reduces visibility, which can depress the spirit of the people, increase hazards to air and ground transportation, and bring on a premature twilight that results in earlier use of artificial light. Residents of cities and towns pay far more than they realize because air pollution adds to laundry and cleaning bills, painting, and other associated costs. The growth and economic progress of some cities have been slowed or brought to a halt by the cumulative adverse effects of dirty air.

MATERIALS DETERIORATION

The 1958-1959 survey in Nashville did not include studies to evaluat materials deterioration resulting from air pollution. It is well known from studies in other areas that damage is caused by soot, tar acids, and gaseous pollutants such as sulfur dioxide in the ambient atmosphere

Sulfur that has been oxidized during a combustion process may, upon release to the atmosphere, unite with atmospheric water vapor to form corrosive acids. The acidity of the atmosphere is closely related to the sulfur content.[55]

Soot and other fine particles play important secondary roles in the corrosion mechanism since the particles make possible the retention of water and absorbed pollutants on surfaces and thus hasten the destruction of materials on which they react. Since tar and tar acids are sticky, they cling to surfaces and have a prolonged corrosive action. This damage is especially apparent on limestone buildings where the adhering particles enhance the attack of atmospheric acids on the carbonate bearing stone by producing gypsum, which is dissolved by rain water, leaving a characteristic pitted surface. A part of the wall around the Tennessee State Capitol Building shows this type of damage. A black crust of soot and smoke deposits has built up on it in places. When pulled off the deposit takes part of the stone with it.

HEALTH EFFECTS IN NASHVILLE AREA

Bronchial Asthma

As part of the Nashville survey, a study was made to determine relationships between bronchial asthma attacks and air pollution. Results of this study have been reported by Doctor L.D. Zeidberg and his co-workers.[56] The summary of this report is as follows:

"A group of 84 patients with bronchial asthma, composed of 49 adults and 35 children reported 3,647 asthmatic attacks during 27,440 person-days of observation, or an overall attack rate of 0.133 per person day. In adults, the asthmatic attack rate varied directly with the level of sulfation in their residential environment.

"Attack rates on days with the highest and lowest sulfur dioxide values were significantly different. When the attack rates were shifted over one day to take account of possible delayed effects, the differences were even more significant. The influence of temperature, humidity, and barometric pressure on the asthmatic attack rate could not be demonstrated, but wind velocity showed an inverse relationship. Pulmonary function tests indicated that subjects with a one-second timed vital capacity of less than 50 percent of the vital capacity had significantly higher attack rates than patients with more than 75 percent function."

Vital capacity, a measure of lung function, is defined as the volume of air that a person can expire in the fullest possible expiration after the deepest possible inspiration.

Sulfation rates refer to the lead peroxide candle method of measuring sulfur dioxide. This method gave results in Nashville that were comparable with those from volumetric sulfur dioxide measurements.

Wind velocities are usually lower when meteorological conditions are conducive to accumulation of air pollutants; therefore, the finding that asthmatic attack rates had an inverse relationship to wind velocity further tends to incriminate air pollution as a cause for increased asthmatic attack rates and indicates the importance of clean air.

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Anthracosis

As part of the Nashville Air Pollution Study, pulmonary anthracosis was studied and reported on in a paper by Doctor Louis D. Zeidberg and his co-workers.[57] A summary of this paper follows (see Figures 29, 30, and 31):

"1. In 641 consecutive autopsis performed at Vanderbilt University Hospital during the years 1953 to 1956, excluding those on subjects under 5 years of age, microscopic evidence of pulmonary anthracosis was sought.

"2. The deposition of anthracotic pigment increased with age; it was more severe in males than in females; and in Nashville residents compared to out-of-city dwellers. Among Nashville residents it increased with length of residence in the city, and was more severe, at least in females, in those who had lived in the more polluted areas of the city. The influence of occupation could not be demonstrated because of insufficient occupational history.

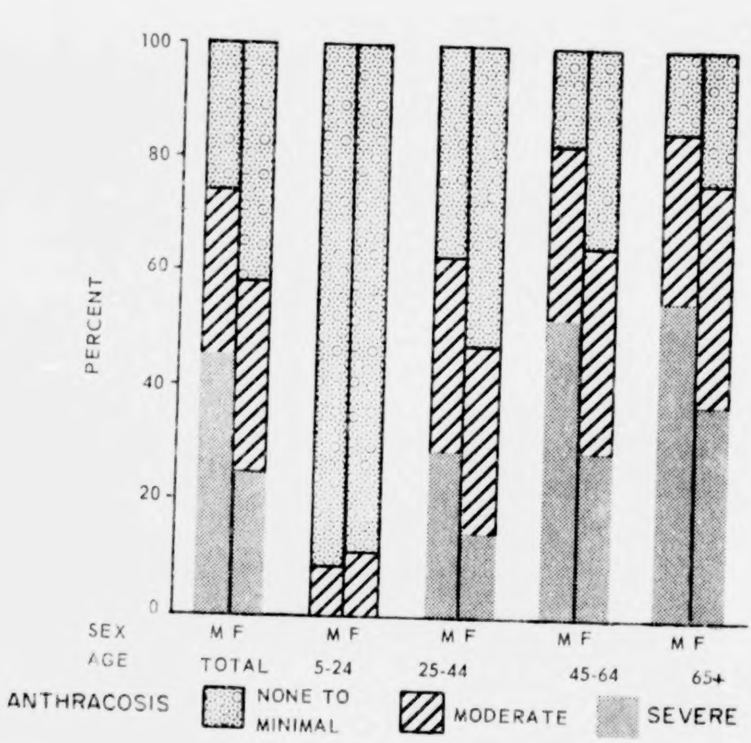


Figure 29. Age and sex differences in degree of anthracosis found at autopsy in 641 individuals at Vanderbilt University Hospital from 1953 through 1956 (See Reference 57).

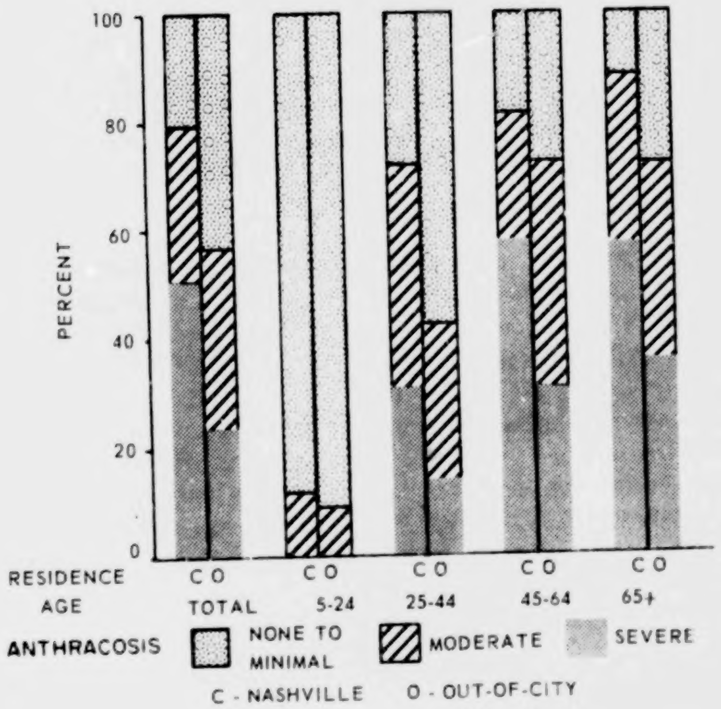


Figure 30. Age and residence differences in degree of anthracosis found at autopsy in 641 individuals at Vanderbilt University Hospital from 1953 through 1956 (See Reference 57).

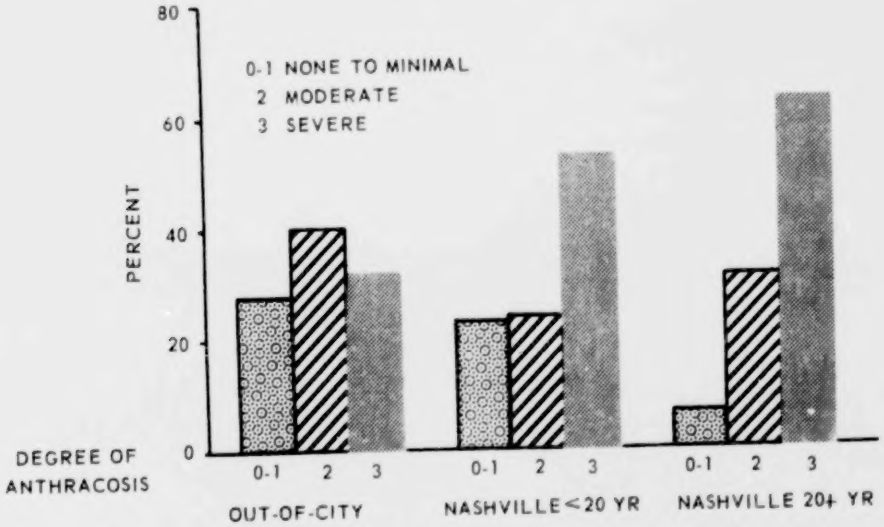


Figure 31. Residence differences in degree of anthracosis found at autopsy in 466 individuals 45 years of age and over at Vanderbilt University Hospital from 1953 through 1956 (See Reference 57).

"3. No association was found between anthracosis and specific pulmonary or cardiac symptoms or pathology.

"4. Pulmonary anthracosis appears to reflect an individual's exposure to environmental air polluted with coal dust."

In the text of the report it is observed that "Failure to associate anthracosis with any other specific pulmonary or cardiac pathology in this study was not surprising. It is well in line with observations made by many other investigators who dealt with the usual kind of pathological material obtained in small sections from collapsed lungs. Only when the lung is inflated to its normal capacity and whole lung sections are made and studied, can the association of anthracosis and focal emphysema be demonstrated."

Dr. Charles P. Oderr of New Orleans has observed that for material he studied, "the common form of chronic emphysema seems to develop first in small localized areas which have a high correlation with trapped perenchymal soot deposits." 58

Anthracosis has been studied intensively as it relates to the occupational hazards in coal mining; however, it has not been as well studied in connection with community air pollution. Considerable difference between occupational and community-air-pollution-caused anthracosis probably exists because of combustion or distillation processes that might tend to destroy or to concentrate toxic chemicals in community air pollutants. There is also evidence that soot particles may absorb gases or liquids from the air and change their toxic potential.

Considerable time may elapse before a definite decision is reached regarding the importance of anthracosis in human health. In the meantime communities will be faced with the necessity of making decisions affecting the levels of anthracosis-producing substances in the air.

Morbidity

Morbidity (sickness) was studied as part of the Nashville Air Pollution Study by Doctor Louis D. Zeidberg and his co-workers. 38 The report summary as it appeared in the *American Journal of Public Health*, January 1964 follows:

"A method for studying the association of air pollution and morbidity in an urban population has been described, and its limitations have been discussed.

"Direct correlations of total morbidity and levels of pollution as measured by the soiling index and 24-hour sulfur dioxide were observed among individuals 55 years old and older of the middle socioeconomic class. Direct correlations for the same aerometric parameters were also noted for cardiovascular diseases, but not for any other specific group of diseases.

"Refinement of analyses to differentiate home and occupational environment influences on morbidity revealed that housekeeping white females manifested direct correlations of pollution and total morbidity for all aerometric parameters, while working white females showed none. Non-white females tended to show direct correlations in both housekeeping and working groups. The effect of pollution on specific diseases of the respiratory, cardiovascular, or gastrointestinal systems could not be demonstrated because such breakdowns produced numbers too small for valid analysis."

Mortality

Mortality (death) was studied as part of the Nashville Air Pollution Study by Doctor Louis D. Zeidberg and his co-workers.[59] A summary of their report as presented to the 91st Annual Meeting of the American Public Health Association in November 1963 is as follows:

"1. The plan of a study of respiratory disease mortality in relation to air pollution, designed to control socio-economic factors as well as degree of exposure to air pollutants, has been described.

"2. With the exception of lung and bronchial cancer, mortality from other respiratory disease varied inversely with the socio-economic class, when the degree of exposure to air pollutants was kept constant.

"3. With the socio-economic factor controlled, respiratory disease mortality was directly related to the degree of exposure to sulfation and soiling, except for lung and bronchial cancer, and for bronchitis and emphysema.

"4. Age-specific respiratory disease mortality rates up to 65 years of age were directly related to the degree of exposure in sulfation. After 65 years, the highest rates were observed in the low pollution group.

"5. At all levels of exposure to sulfation, respiratory disease mortality rates for males were higher than for females. The difference was especially marked for lung and bronchial cancer mortality.

"6. With the exception of lung and bronchial cancer, respiratory disease mortality rates for non-whites were higher than for whites at high and moderate levels of exposure to sulfation.

"7. The deviation of mortality for lung and bronchial cancer, and for bronchitis and emphysema from the pattern shown by other respiratory diseases has been discussed."

VISIBILITY

When the moisture content of the air, as measured by relative humidity, is below 70 percent, the primary factor influencing visibility is suspended particulate matter. The obscuring ability of this airborne matter is dependent primarily on the number of particles and their size. Large particles usually contribute the most weight to an air pollution sample, but small particles, those of 1 micron diameter and smaller, scatter the most light and normally cause most of the decrease in visibility.

During the Nashville survey, visibility observations were made in the morning and afternoon from the roof of the Cordell Hull Building toward the west, north, and east. Data reported here are for the period September 17, 1958, to February 28, 1959. The results summarized in Table 24 are for periods when the relative humidity was below 70 percent. Visibility is always reduced more toward the west of this observation point than it is in any other direction because pollution levels are relatively high in this direction (see Figures 13, 18, and 20). Afternoon observations, in general, show an improvement over morning conditions, probably because solar radiation promotes better vertical dispersal of pollutants. The winter season visibility is poorer than that of the fall season. This is probably a reflection of a greater air pollution load during the winter months.

California standards for ambient air quality declare that an "adverse" level of particulates has been reached when they are "sufficient to reduce visibility to less than 3 miles when the relative humidity is less than 70 percent. 44 Applying this standard to Nashville reveals that "adverse" conditions existed on 20 of the 37 low-humidity days in the winter season and on 15 of the 33 low-humidity days in the fall season.

The appearance of Nashville on days of high particulate loading and reduced visibility is not pleasing. Photographs taken at times of low and high pollution (Figures 32 and 33) are typical. Surely all would agree that the low-pollution day would be the much more desirable of the two.

PUBLIC CONCERN ABOUT AIR POLLUTION

As part of the morbidity survey done in the Nashville area in 1958-59, a study was made to find out whether people were aware of air pollution and whether they were bothered by air pollution and its adverse effects. 60 People in 3,032 dwelling units were interviewed.

Table 24. FREQUENCY OF REDUCED VISIBILITY IN NASHVILLE; RELATIVE HUMIDITY LESS THAN 70 PERCENT[a]

	9 a. m.			3 p. m.		
	West	North	East	West	North	East
Fall season[b] visibility, miles						
1/2	5	4	7	0	0	0
1	5	5	4	4	0	0
1-1/2	0	5	0	2	1	0
3	5	2	1	8	2	0
4	11	7	4	18	10	1
6	6	4	10	1	5	13
Total days visibility reduced	32	27	26	33	18	14
Days with no visibility reduction	1	7	5	2	17	21
Total number of days	33	34	31	35	35	35
Percent of days with reduced visibility	97	79	84	94	51	40
Number of days visibility reduced to 3 miles or less[c]	15	16	12	14	3	0
Winter season[d] visibility, miles						
1/2	7	8	10	1	0	0
1	7	7	3	3	3	2
1-1/2	5	2	2	5	3	2
3	1	7	3	5	4	3
4	11	6	7	20	13	11
6	6	1	10	4	3	10
Total days visibility reduced	37	31	35	38	26	28
Days with no visibility reduction	0	6	0	0	12	10
Total number of days	37	37	35	38	38	38
Percent of days with reduced visibility	100	84	100	100	68	74
Number of days visibility reduced to 3 miles or less[c]	20	24	18	14	10	7

[a] Period of observations - September 17, 1958, to February 28, 1959.

[b] September, October, November.

[c] California standard relating to the "adverse" level of particulates.

[d] December, January, February.

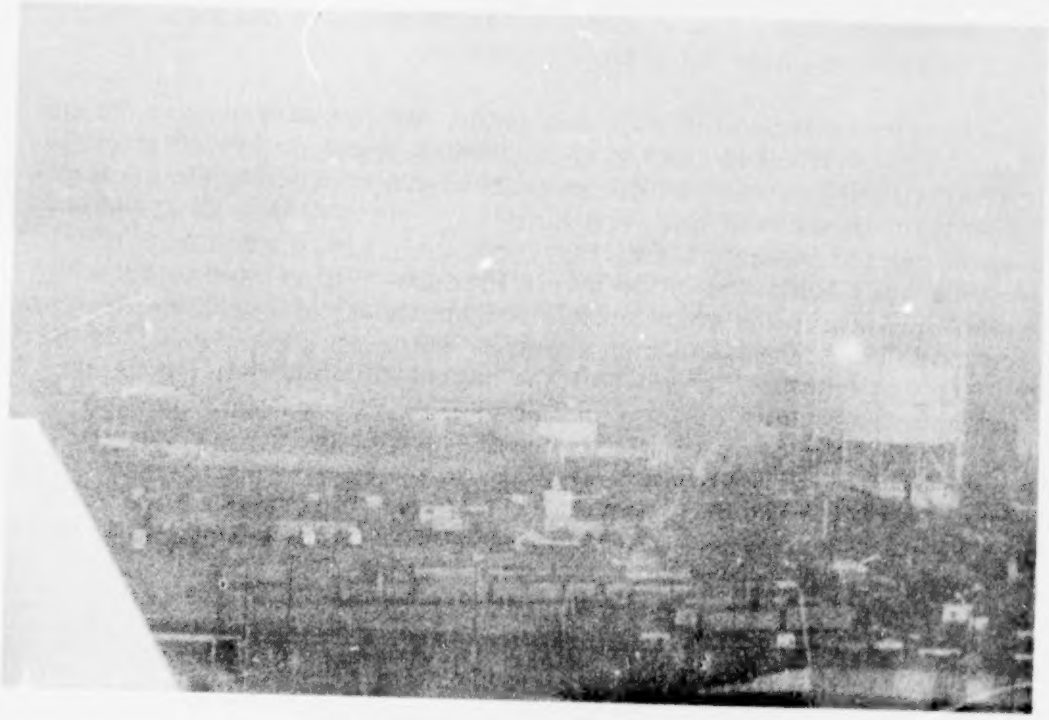


Figure 32. Photograph taken from Cordell Hull Building on dense air pollution day.

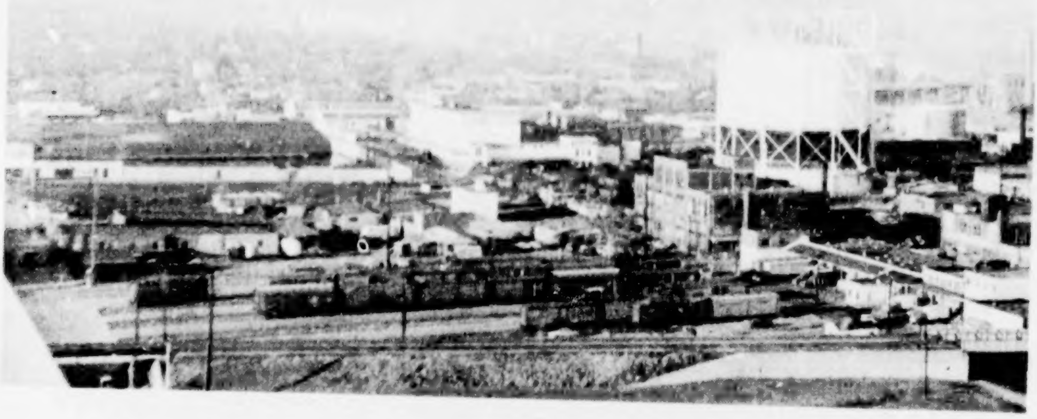


Figure 33. Photograph taken from Cordell Hull Building on relatively clear day.

The questionnaire was carefully designed to prevent bias, and the people were not aware that the interview had, as its primary purpose, study of various facets of the air pollution problem.

The hypothesis postulated in this public opinion survey was: "If the people of Nashville were aware of air pollution and concerned about its effects, indications of public awareness and concern would be at a higher level in areas of higher pollution and vice versa." Responses to questions did indicate significant increasing awareness and concern about air pollution as pollution levels increased (as related to actual aerometric data in the respondent's neighborhood) (Figure 34). Women were more concerned than men about air pollution. The higher the socioeconomic status, the greater the correlation between degree of concern and air pollution levels. Depending on the category of complaint, from 18 to 51 percent of the people interviewed were bothered by such matters as soiling of homes, automobiles, furnishings, and laundry; bad smells; haze in the air; and deterioration of metals (Table 25). These data leave no doubt that the people of Nashville believe that their air is dirty.

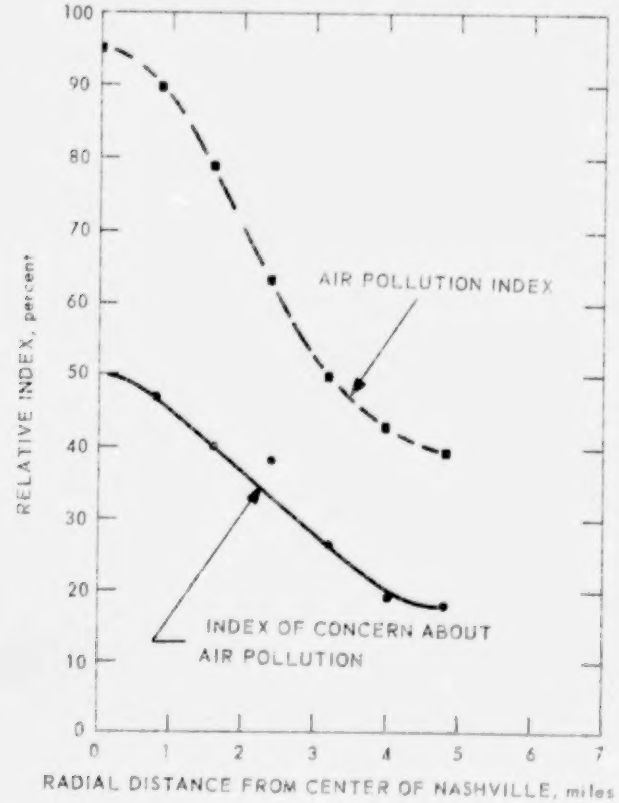


Figure 34. Radial distribution from center of Nashville of air pollution levels and public concern about air pollution (See Reference 60).

Table 25. RESPONSES TO DIRECT QUESTIONS ON AIR POLLUTION IN PUBLIC OPINION SURVEY[a]

Question	Percent "yes" of applicable responses
Are you bothered with smog?	23.0
In the area where you live are you bothered by:	
a. Outside of the house getting dirty fast?	36.5
b. Frequent bad smells in the air?	26.2
c. Automobile getting dirty fast?	44.3
d. Too much dust and dirt collecting on the porch, window sills, etc?	51.2
e. Frequent haze or fog in the air?	28.9
f. Walls, curtains, and furniture getting dirty too fast?	48.7
g. Laundry getting dirty while hanging out to dry?	34.6
h. Screens and gutters wearing out fast?	18.4

[a] Taken from Reference 60.

A summary of major conclusions given in the full report on this survey[60] are as follows:

"1. An extension of the sample population to the total Nashville population shows that about 50,000 of the 232,000 residents were bothered by smog (air pollution in general); and from 40,000 to 100,000 residents were bothered by effects of air pollution such as soiling of surfaces and objects, decreased visibility, odors, and damage to property.

"2. Thirteen percent of the respondents living in the City of Nashville felt that the city did not do a good job of keeping the city clean.

"3. The people's awareness of, and concern about, air pollution was influenced more by frequency of occurrence of days of unusually high pollution than by high monthly, seasonal or annual average pollution levels."

The third conclusion, if proved true in a general sense, indicates that people's desire for clean air may be reached by preventing the unusually high pollution levels that occur on a relatively small number of days. Measures to accomplish this would be somewhat different than measures designed to reduce pollution by the same amount at all times. They would be measured by 99th percentiles on frequency distribution graphs of pollutants.

MATHEMATICAL AIR POLLUTION DIFFUSION MODELS AS AIDS TO ZONING, PLANNING, AND PROGRAM DECISION MAKING

There were two air pollution diffusion models tested in connection with the Nashville study. The first, sulfur dioxide, used meteorological and emission data covering 2-hour periods to give calculated levels of sulfur dioxide that were compared with corresponding 2-hour volumetric sulfur dioxide measurements. The final results, both calculated and measured, were 24-hour means. The second diffusion model, sulfation, utilized published monthly meteorological summaries of hourly observations and the same basic sulfur dioxide emission data as was used in the first model test. Its output, monthly average sulfation rates, was compared with measured sulfation values.

PURPOSE OF MODELS

Community decisions often have major effects on air pollution levels. For example, a community has a major odor problem due to an inadequate sewer system or sewage treatment facilities. If that community made a decision to construct adequate sewers and treatment facilities, the odor would in due time be abated. A decision to do nothing would assure the continuation of the odor problem. Many examples of community decisions that would either increase or decrease air pollution can be mentioned. It is extremely important, therefore, to consider air pollution within the decision-making process of the community.

To a considerable extent, in the present-day metropolitan area, decisions center around the planning process, with resultant action reflected in zoning ordinances and individual guidance based on the comprehensive plan in its several parts. The present trend of planning commissions to utilize machine data-handling systems (electronic computers and others) facilitates study and analysis of air pollution problems. For example, data cards pertaining to land use could readily include information concerning the air pollutants emitted on each parcel of land. Furthermore, it appears possible to utilize this basic system through suitable computer programming to analyze air pollution problems, and predict air pollution levels. A start toward the development of such a system was made during the Nashville study.

TEST OF VOLUMETRIC SULFUR DIOXIDE DIFFUSION MODEL

One mathematical air pollution diffusion model tested in Nashville relates air pollution emission rates and meteorological diffusion parameters by use of an IBM 7090 computer program. The end results are maps showing predicted air pollution levels attributable to residential, commercial, and industrial pollution sources. The model, developed from existing diffusion knowledge, was tested at Nashville by measuring actual sulfur dioxide levels and comparing them with calculated (predicted) levels. Further details of the model capabilities and limitations are reported in a paper by D. B. Turner.[61]

According to the manuscript 58 percent of all calculated sulfur dioxide concentrations were within 0.01 ppm of measured concentrations and 86 percent were within a factor of 2 ± 0.01 ppm of the calculated values. It further reports a tendency of the model to overcalculate sulfur dioxide concentrations. This tendency may well be influenced by a preliminary (since corrected) overestimation of sulfur dioxide emissions as described in the section on "Sources of Air Pollutants." The model is discussed here with a recognition that refinements are needed for general application, but also with the knowledge that it has been tested for Nashville, and that its capabilities and limitations are known for that city.

APPLICATION OF SULFUR DIOXIDE DIFFUSION MODEL

Pollution source strengths, in the present case sulfur dioxide emission rates, were taken from the sulfur dioxide emission inventory prepared by H.J. Paulus and his co-workers and reported by Stalker et al.[11] These emission rates were for commercial, residential, and industrial sources; therefore, calculated sulfur dioxide concentrations attributable to each source type were known. Total emission for each square mile in the area and the percent of the total area-wide emission from each square mile were plotted on maps. Figure 35 is an example of this information for an average winter day. Emissions for space heating were considered by 2-hour periods to establish the diurnal variations during the day. A day covered the 24-hour period from 2 p.m. to the same time the following day. In the use of the model reported here, the assumption was made that all residential emissions occurred at 10 meters above ground level, commercial emissions 25 meters above ground level, and industrial emissions 45 meters above ground level.

Eight days were selected for purposes of this report for making predicted (calculated) estimates of ambient-air sulfur dioxide concentrations. Seven of these were selected from among the 8 days during the 1958-59 study when area-wide 24-hour average sulfur dioxide concentrations were higher than on any other day (Table 26). These days were selected because of the great interest in days of high polution and because unavoidable inaccuracies in air pollution measurements are less significant when concentrations are high. The day with the fourth highest sulfur dioxide level was not used because precipitation

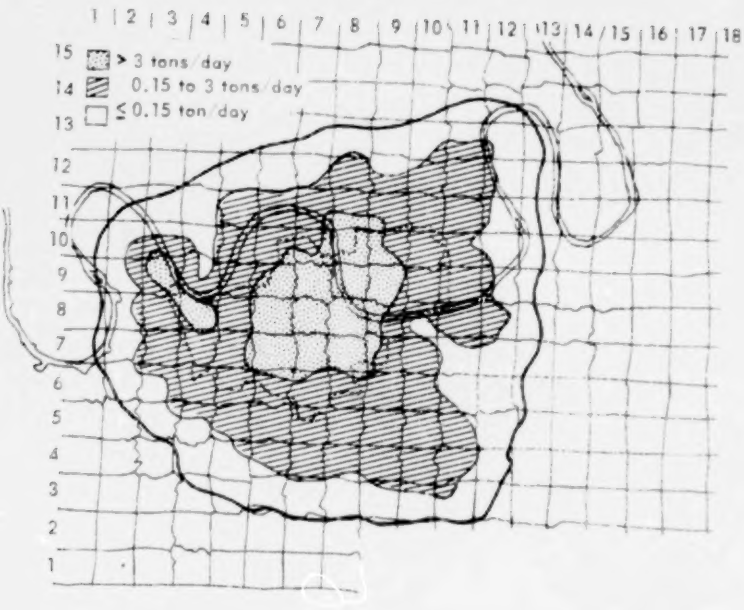


Figure 35. Mean winter-season sulfur dioxide emission calculated, Nashville community air pollution study, square-mile-area boundaries (See Reference 11).

Table 26. RANK OF SULFUR DIOXIDE LEVELS ON DAYS SELECTED FOR APPLICATION OF DIFFUSION MODEL

Date	Rank[a] among all days from August 1958 to July 1959 according to observed 24-hour area-wide sulfur dioxide concentration
Dec. 20-21, 1958	1
Dec. 21-22, 1958	2
Dec. 11-12, 1958	3
Jan 10-11, 1959	5
Nov. 30-Dec. 1, 1958	6
Dec. 7-8, 1958	7
Nov. 21-22, 1958	8
Jan. 28-29, 1959	40

[a] High to low.

occurred on that day. The diffusion model is not expected to give good results when rain occurs. The 40th ranking day (January 28-29, 1959) was selected because sulfur dioxide emissions for that day were representative of the average for January 1959.

The high pollution levels experienced on the 7 days selected for study were associated with low wind speeds, as expected. In Table 27

Table 27. WIND SPEED FREQUENCIES FOR DAYS SELECTED FOR APPLICATION OF DIFFUSION MODEL AND FOR A 5-YEAR PERIOD

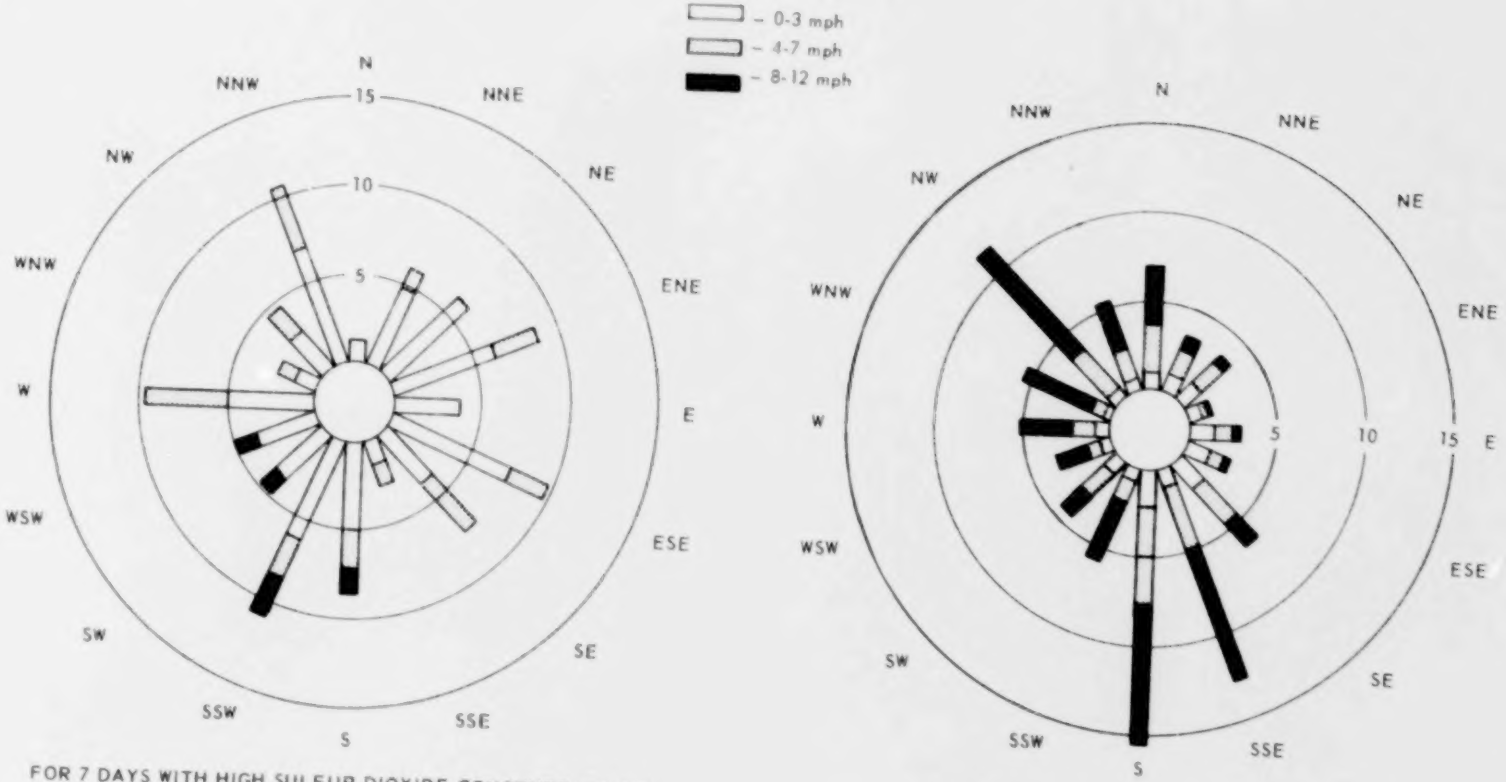
Wind speed, mph	% of occurrence		
	7 selected days	Oct.-Mar. (5 yr)	Apr.-Sept. (5 yr)
0 - 3	66.6	22.8	33.2
4 - 7	27.4	30.2	37.3
8 - 12	6.0	25.8	21.7
13 - 18	0	17.3	7.3
19 - 24	0	3.2	0.3
25 - 31	0	0.5	0.1
32 - 38	0	0.2	0.1

and Figure 36 wind speeds on the selected days are compared with normals determined over extended time periods. Notice that the proportion of 0-3-mph wind speeds for the 7 selected days was 2 and 3 times greater than those for the longer-time-average periods.

Using the sulfur dioxide emission data, actual meteorological data for the respective days, the mathematical air pollution diffusion model and machine data processing, calculations were made of predicted sulfur dioxide concentrations at the center of each square mile on a 9- by 11-mile grid system superimposed on the Nashville area. Separate concentrations were calculated for sulfur dioxide due to residential, commercial, and industrial sources of the pollutant. Lines were drawn connecting locations of equal sulfur dioxide concentrations due to each of the three types of pollution source. The results are shown in Figures 37 through 44. Concentrations due to each type of source may be added together to get the total sulfur dioxide level at any point in the area on a particular day. This method of plotting makes it possible to determine at a glance the importance of each type of source on pollution levels in any particular area on a given day.

The prediction maps can and should be used as a guide in locating new installations that may emit sulfur dioxide air pollution. For this use, the probable contribution of the new source or sources should be calculated and added to those levels indicated on the prediction maps. This will aid in deciding whether the prospective level is acceptable or whether a different location should be found for the installation or controls placed on that and other contributing sources.

The prediction maps can be used to determine the range and magnitude of influence of residential, commercial, and industrial emissions of sulfur dioxide. These, in turn, will assist in consideration of the effect of certain decisions, for example, the elimination of home heating with sulfur-bearing coal. The maps would reflect this change as elimination of all residential source contribution isopleths.



FOR 7 DAYS WITH HIGH SULFUR DIOXIDE CONCENTRATIONS

PERIOD OF NOVEMBER 1945 – FEBRUARY 1954

Figure 36. Percentage frequency of wind direction and speed in Nashville.

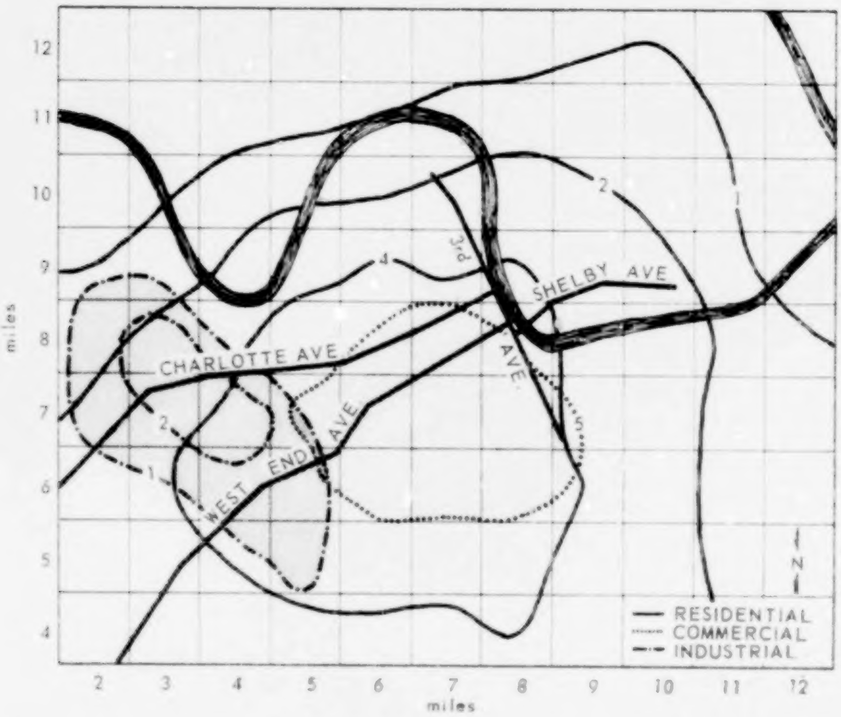

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Figure 37. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration in parts per hundred million (pphm) in Nashville on Dec. 20, 21, 1958.

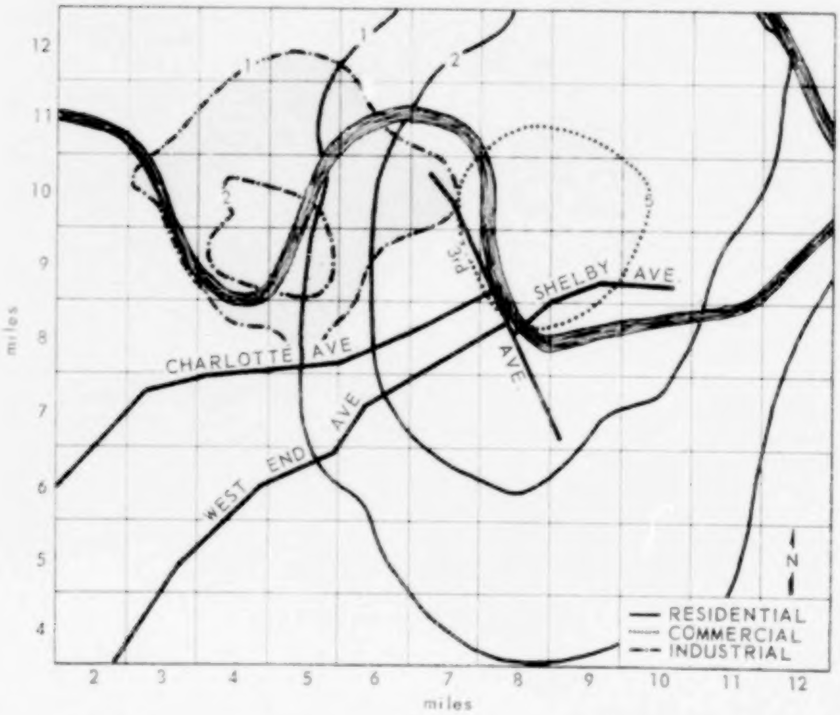
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Figure 38. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Dec. 21, 22, 1958.

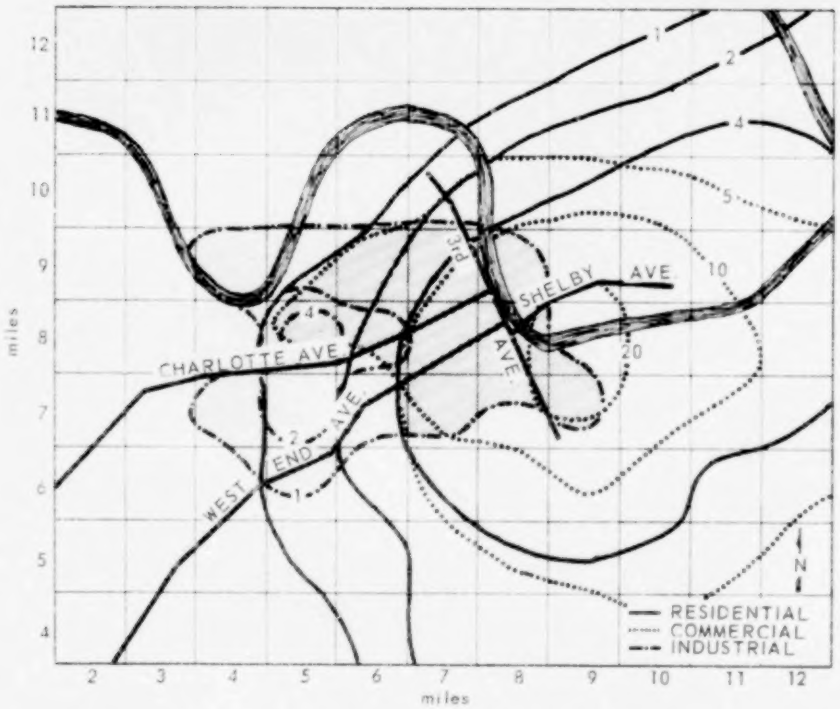
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Figure 39. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Dec. 11, 12, 1958.

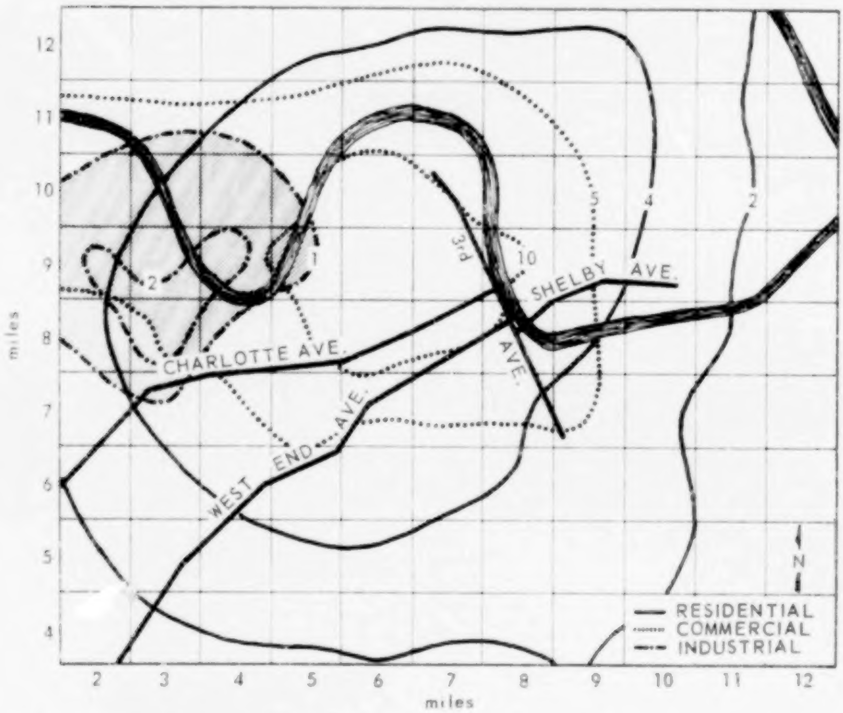
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Figure 40. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Jan. 10, 11, 1959.

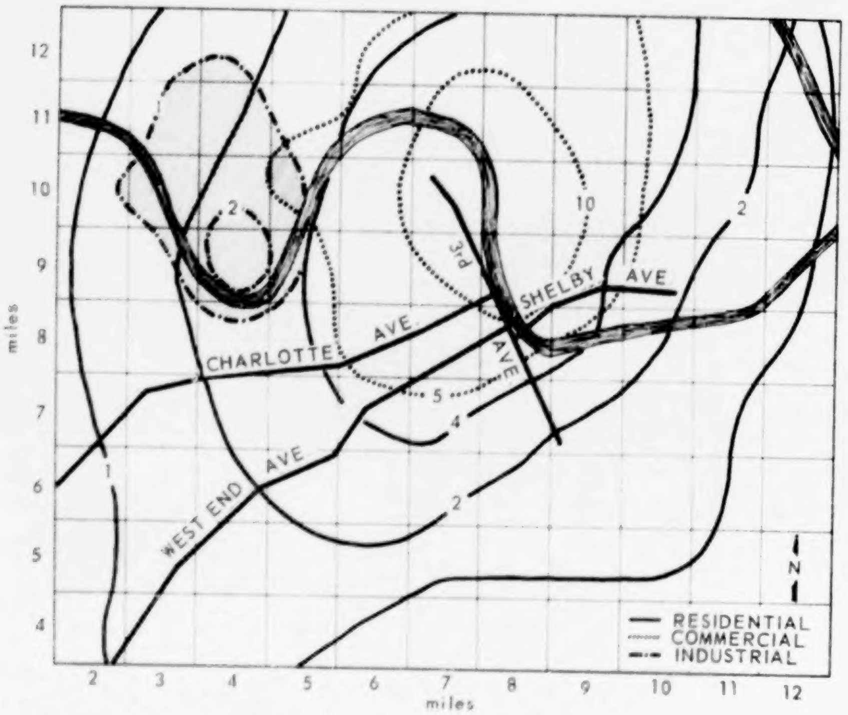

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Figure 41. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Nov. 30, Dec. 1, 1958.

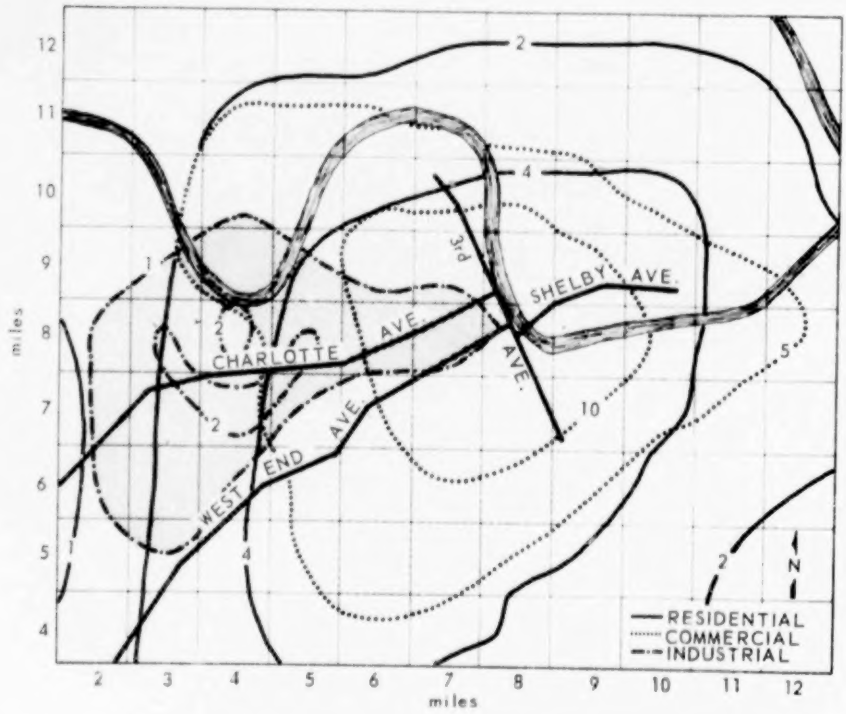

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Figure 42. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Dec. 7, 8, 1958.

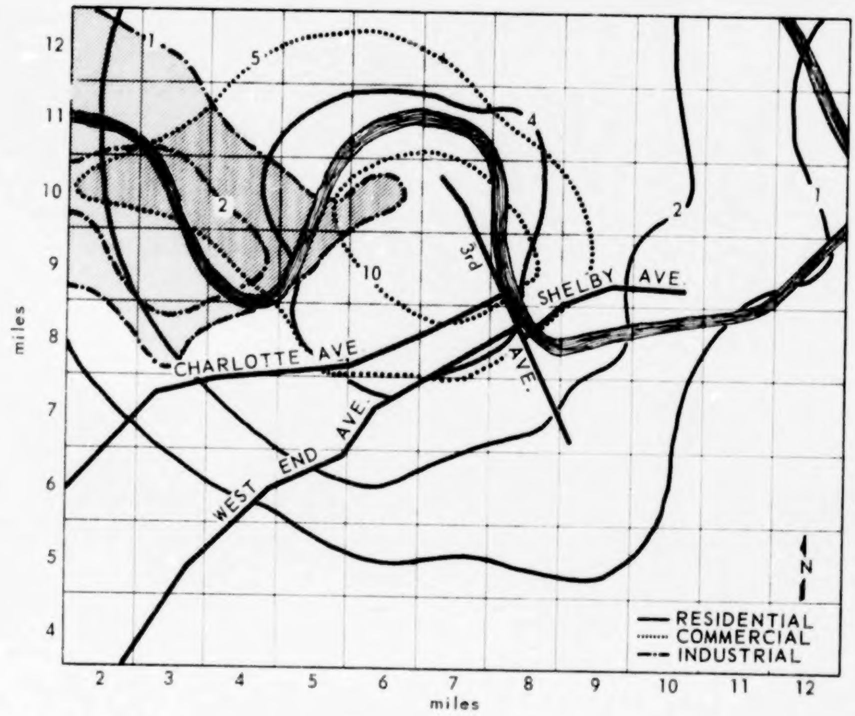
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Figure 43. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Jan. 28, 29, 1959.

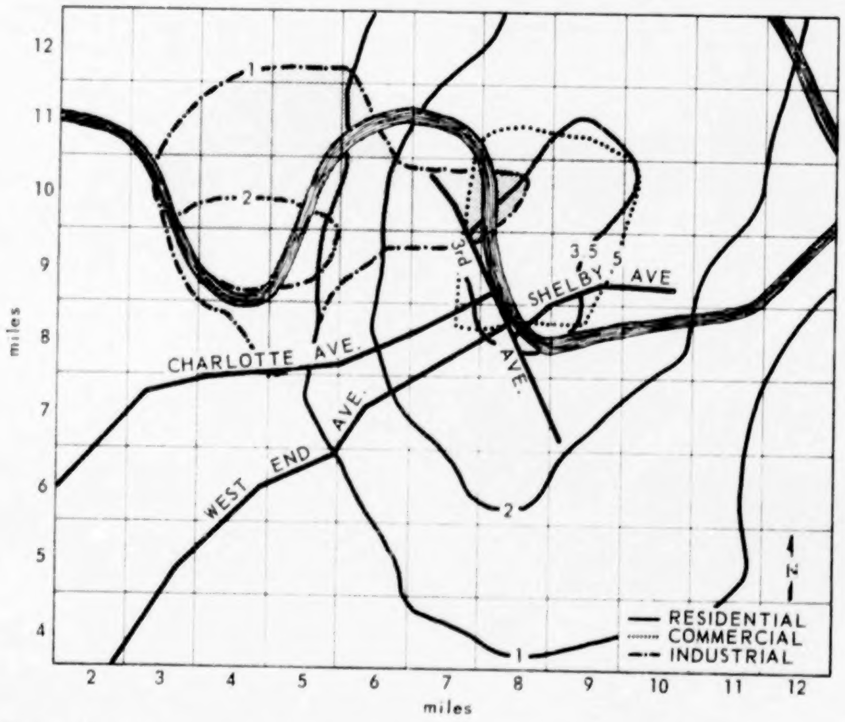
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Figure 44. Mathematical diffusion model test, predicted 24-hour average sulfur dioxide concentration (pphm) in Nashville on Nov. 21, 22, 1958.

If an area zoning change were being considered, sulfur dioxide levels for the square mile or miles involved should be determined from the maps. For example, if square mile East 3, North 9 is considered, the following values for the 7 high days are obtained: 0, 1, 0, 12, 3, 3, and 0 pphm (by volume) of sulfur dioxide. This gives a predicted average for the 7 days of 2.7 pphm (0.027 ppm), which is acceptable according to the suggested goal of 0.1 ppm maximum 24-hour mean value. If the square mile East 7 and North 8 is selected, the following values are obtained: 9, 2, 15, 14, 9, 15, and 2 pphm. This gives an average for the 7 days of 9.4 pphm (0.094 ppm). For the 3 maximum days, values are 15, 15, and 14 pphm; the average is 0.15 ppm, which is above the 0.1 ppm suggested goal. It can be anticipated that the maximum instantaneous value would be about 3 times the average, or 0.45 ppm.

Although beyond the capability of the present operation, yearly or seasonal averages or time and frequency of concentrations could conceivably be predicted through more extensive use of the model and computer. The model could also be used to predict ambient air concentrations of any gaseous pollutant for which emissions can be determined and atmospheric decay rates are known.

These diffusion model studies in Nashville were based on the TCM (West & Gaeke) method for measuring sulfur dioxide. Although this is considered to be a precise and reliable method, it may, give values somewhat lower than true values (see Sulfur Dioxide Measurement section of this report).

TEST OF SULFATION DIFFUSION MODEL

The test and development of this diffusion model is reported in a paper entitled "A Prediction Model of Mean Urban Pollution For Use With Standard Wind Roses." 62 The abstract of this paper is as follows:

> "An empirical diffusion equation was used with published summaries of wind direction and speed frequencies obtained at the Nashville Weather Bureau station to compute patterns of mean monthly relative concentrations. The patterns consisted of the relative concentration contributions from grid points at 1-mile intervals to the central grid point. An estimate of SO_2 emissions for each square mile of the Nashville area was combined with these relative concentration patterns, using an electronic computer to obtain patterns of mean monthly SO_2 concentrations. Computations were made for 5 principal space-heating months.
>
> A network of 123 lead peroxide candle measurement sites provided patterns of observed SO_2 concentrations. While the absolute magnitude of the concentrations predicted could not be verified, due to cumulative uncertainties in the source inventory, and in the interpretation of the candle measurements, the error of prediction

is considered to be less than a factor of two. Predicted and observed patterns were generally similar, with a superimposed topographic effect on observed concentrations. Hillside locations facing towards the sources showed generally higher than predicted values, and valley locations sheltered from the sources by intervening terrain, lower values.

Relative monthly emission rates determined from a comparison of predicted and observed values for the area showed a close linear relationship to monthly degree-day totals, for the 5 months considered. A dropoff from the linear trend could be noted for non-heating and transitional months."

APPLICATION OF SULFATION DIFFUSION MODEL

The application of this model is essentially the same as that for the model using volumetric sulfur dioxide measurements. The limitations and exceptions are primarily related to the inability to interpret sulfation results. Sulfation cannot be related specifically to sulfur dioxide; therefore, the criteria that apply to sulfur dioxide effects do not apply directly to sulfation measurements. Furthermore, it is quite possible that other pollutants affecting the sulfation rates may be fully as important as sulfur dioxide. An additional complication arises since the long-term averages provided by this diffusion model and the sulfation measurements do not relate to effects from sulfur dioxide or other known air pollutants that enter into sulfation reactions because these effects generally relate to exposures of less than 1 day.

A PROPOSAL FOR AN AIR RESOURCE MANAGEMENT PROGRAM FOR NASHVILLE METROPOLITAN AREA

ELEMENTS OF AIR RESOURCE MANAGEMENT PROGRAMS

The concept of air resource management as compared with and contrasted to air pollution control is in its infancy; however, some major activity areas are now evident. They are:

1. A continuing air quality monitoring program. As part of this function, the effects of air pollution on public health and welfare, property, vegetation, and visibility will be determined continually.

2. A current and continuing emission inventory. This is a tabulation of the air pollutant emissions of consequence from any and all sources. Because it relates to air use, it has much in common with land use, a planning term. This relationship, in turn, calls for coordination of responsibilities and activities of agencies involved in land-use planning and zoning, and air pollution control.

3. Air quality goals or standards, based on air quality criteria. This, in essence, is a definition of the air quality sought for the area. The organization and methods by which these goals are to be adopted in the Nashville area need to be determined.

4. A thorough knowledge and use of the conditions influencing the transport of air pollutants. This involves meteorological and topographical factors influencing diffusion characteristics of the air mass. In due time, this knowledge helps provide a better understanding of reactions taking place in the air and losses of air pollutants with time after emission from sources.

5. Community planning decisions based on air quality goals. In time this activity will provide an effective means for the prevention of air pollution, assure conservation of the air resources, and assure use of the air resource that is in the community's best interest.

6. Air pollution control decisions and resulting ordinances based upon the information and scientific determinations made regarding air quality. This activity involves development of land-

and air-use plans and pollutant emission regulations and their implementation, provision for preventing emission of excessive pollutants from new establishments, negotiation of specific abatement plans for individual and classes of sources, and determination of violation of various legal requirements. In this activity the legal force of the community is used in preventing and controlling emission of pollutants into the atmosphere. This area should receive substantial attention because its success is essential.

GENERAL OUTLINE OF NASHVILLE METROPOLITAN AREA PROGRAM

The data available on pollution levels in the air over the Nashville Metropolitan Area and the adverse effects of this pollution make it clear that a comprehensive, air resource management program should be established. The organizational structure needed to do so must be determined within the framework of the general reorganization under way since adoption of the metropolitan form of government. This type governmental organization enhances the possibility of establishing an air resource management program that covers the air pollution basin adequately.

Ordinances should be written to establish an air resource management program and to provide for its organization, financing, and operation. Provision should be made for the following:

1. Establishment of an administrative organization to carry out the purposes of the ordinance.
2. A mechanism for adopting detailed rules and regulations needed to implement the purposes of the ordinance.
3. A means for ensuring that new establishments are provided with adequate facilities for preventing pollutant emissions.
4. Regulatory functions and their relationship to other governmental activities, especially those of planning, zoning, and building regulation.
5. Establishment of air quality goals.
6. Maintenance of a continuing air pollutant emission inventory.
7. Conduct of air quality monitoring and other necessary studies, surveys, and investigations.
8. Conduct of hearings and mechanisms for considering granting of variances from provisions of the ordinance or specific rules or regulations in certain situations.

9. A schedule of fees for various permits, inspections, tests, etc., if desired.

10. Judicial processes and penalties to apply in cases in which persons fail to comply with the ordinance or rules or regulations.

The money needed to operate a comprehensive governmental air resource management program in Davidson County is estimated to be $100,000 to $160,000 per year (1964). This level of activity could best be achieved over a period of about 2 years to permit orientation and training of new staff members and orderly acquisition of equipment and facilities. Although not part of an air pollution ordinance, provisions for financing and personnel policies are central to the success of the program.

Some specific elements of the proposed Davidson County air resource management program and certain key pollutant emission control measures that should be provided for by ordinance or rule or regulation are discussed in the following sections.

AIR QUALITY MONITORING

There are two major needs to be met in air quality monitoring in the Nashville Metropolitan Area. The first of these relates to the establishment of long-term trends in air quality. The second has to do with the collection of air quality information needed for regulatory, planning, and air conservation activities. These activities should all be part of the comprehensive air resource management program.

Sulfur Dioxide

The long-range phase of the sulfur dioxide monitoring program could be carried on best with a continuous-recording automatic sampler located in the central city area and with seven or more lead peroxide candles distributed throughout the area to follow trends of monthly and seasonal average levels as well as changes in the pattern of the geographical distribution of sulfur dioxide. Operation of this network every third year would be adequate.

For the phase of the program related to regulation of specific sources, it would be advantageous to have two portable continuous-recording sulfur dioxide analyzers, which could be readily transported and placed in operation. If continuous-recording instruments are not feasible, sequential samplers could be used at a lesser cost for equipment, but with some sacrifice in usefulness of data obtained.

Suspended Particulates

Suspended particulates should be measured by means of the Hi-Vol sampler and the AISI strip filter paper sampler. The former would measure suspended particulates on a weight basis, and the latter would indicate the soiling characteristics of airborne particles. Information obtained from the 1958-59 Nashville study indicates that one centrally located sampling station would be sufficient to monitor long-range trends. Three or four samplers of both types should be used from time to time in connection with specific source control operations of the program.

Dustfall

Even though dustfall measurements are not as meaningful as would be desirable from a technical standpoint, they do represent the most commonly used method of measuring particles that cause soiling of horizontal surfaces. When conducted in a uniform manner over a period of years and when data obtained are properly interpreted, these measurements provide an index of the dustfall situation. It is, therefore, suggested that seven or more dustfall collectors be operated on a monthly cycle on a continuing basis. The locations could well coincide with location of the lead peroxide cylinders used to measure sulfur contaminants.

Oxidants

An automatic recording instrument would be desirable for measurement of oxidants. If it could not be justified because of cost, short-time manual sampling near noontime each day could be substituted. This would be directed toward finding oxidant levels in the central part of the city as an index of the photochemical smog situation. Operation during the months of April through October would be adequate since photochemical smog is not anticipated in colder months of the year.

Complaint Records

A continuing, complete, and organized list of all air pollution complaints is a valuable means of program orientation that augments technical air quality measurements. Complaints can be used also to help locate troublesome single sources of pollution and provide considerable indication of public reaction to generalized pollution levels. This program phase should be organized to show the geographical distribution of complaints as well as their type and time of occurrence. The form in Table 28 is suggested for program use in Nashville. Its use should be keyed to the map grid system discussed under the Diffusion Model section of this report.

Table 28. AIR POLLUTION COMPLAINT RECORD

NO. ☐☐☐☐☐
cc. 2-6

SOURCE NAME: ______________________ PREVIOUS RECORD: Yes ☐ 1 No. ☐ 2
cc. 1

ADDRESS: ______________________

CITY: ______________________ COORDINATES X ☐☐☐ Y ☐☐☐
cc. 8-14

TYPES OF PREMISES: cc. 15 Industrial 1 ☐ Commercial 2 ☐ Public Bldg. 3 ☐ Private Res. 4 ☐

DATE OF COMPLAINT: Month ☐☐ Day ☐☐ Year ☐☐ cc. 16-21 TIME: ☐☐☐☐ cc. 22 AM ☐ 1 PM ☐ 2

NATURE OF COMPLAINT: cc. 23

Smoke ☐ 1
Soot ☐ 2
Flyash ☐ 3
Pollen ☐ 4
Fumes ☐ 5
Dust ☐ 6
Spray ☐ 7
Odor ☐ 8
Other ☐ 9
(Specify__________)

SOURCE OF COMPLAINT: cc. 24

Industrial Process ☐ 1
Boiler ☐ 2
Incinerator ☐ 3
Furnace ☐ 4
Motor Vehicle ☐ 5
Open Burning ☐ 6
Demolition ☐ 7
Sewage ☐ 8
Other ☐ 9
(Specify)

COMPLAINANT:

Name ______________________ Telephone __________ Coordinates X ☐☐☐ Y ☐☐☐
cc. 25-30

Address ______________________

Received by: ☐☐☐ cc. 31-33 Via phone ☐ 1 cc. 34 Letter ☐ 2 In person ☐ 3

EFFECT OF ALLEGED POLLUTION: cc. 35

Soiling ☐ 1
Corrosion ☐ 2
Reduced Visibility ☐ 3
Eye Irritation ☐ 4
Throat ☐ 5
Nausea ☐ 6
Obnoxious Odor ☐ 7
Vegetation Damage ☐ 8
Other ☐ 9
(Specify__________)

Inspection following complaint: Yes ☐ 1 No ☐ 2
cc. 36

APPRAISAL OF EFFECTS OF AIR POLLUTION

Studies of effects of air pollution on the health of the people of the Nashville area made in 1958-59 have provided much useful information. Followup studies and studies of other aspects of potential health effects would be desirable. Such studies are of a research nature; they require highly skilled specialized personnel who probably will not be available within the community government. Universities in the area, which are equipped to perform these studies, should be encouraged to do (or continue) work in this field. Funds could be provided in part by the local government. Other potential sources of funds are various foundations, the Federal Government, and voluntary health organizations.

Methods of measuring effects of air pollution on materials, such as soiling and corrosion, are not well established. Certain studies can and should be made by, or under, the auspices of the Nashville area air pollution control agency. Since the soiling capacity of Nashville's air has been shown to be rather high, emphasis should be placed on determination of the economic costs of soiling of buildings, furnishings, clothing, etc. Information of this kind will be of assistance from time to time as questions concerning the economic aspects of various pollutant emission control possibilities are raised.

The visible manifestations of air pollution are, to many people, the principal index of air quality. Everyone notices decreased visibility. Since decreased visibility is an important effect of air pollution in the Nashville area, routine observations of visual range should be made on a continuing basis. One observation at 8 a.m. and perhaps another at 10 a.m. daily would provide useful information over a period of years. Relative humidity measurements would need to be made at the same times for evaluation of the visibility observations.

Vegetation, particularly certain species, is susceptible to damage by air pollutants. Some species react in a specific known way to certain pollutants at certain concentrations. Surveillance of vegetative reaction to pollutants can provide information about identity and concentration of pollutants and also indicate adverse effects on plants due to pollutants. At least a modest program of inspection of sensitive vegetation is recommended. Since a skilled, specialized person is required, the local government might find it best to secure the part-time services of a qualified person from a local university.

AIR POLLUTANT EMISSION INVENTORY

The emission inventory is an essential part of an air resource management program. Providing information on sources, quantities, and qualities of pollutants put into the air assures orientation of the air resource management program to the principal problems. At the same time it provides a "yardstick" to measure the reasonableness and effectiveness of emission limits directed toward meeting air quality goals.

The emission information contained in this report will serve as a program basis for a limited period of time. The existing data will have to be supplemented to keep up to date on a continuing basis.

All major sources of air pollutants should be required to report yearly on materials discharged into the atmosphere. This reporting could be considered a conservation measure and one which is, in the long run, good business. In an economic and product production sense the pollutants put into the air would constitute one part of a process materials balance. Certain sources, however, such as automobiles, refuse burning, home heating, and related items, would need to be inventoried directly by the air pollution agency. The U. S. Bureau of the Census, Census of Manufacturing, and Census of Housing publications are valuable aids for preparing certain inventory parts. In some instances, census data can be related to census tracts to show the geographical distribution of emissions. The emission inventory activity should be coordinated with the activities of the Planning Commission. Air pollution emissions are actually air use items closely related to land use. Coordinated and cooperative activity between the air pollution control agency and the planning agency could be an effective and efficient way to maintain an emission inventory. In Nashville, this may not be feasible at this time, but it should be a goal linked with the use of automatic data processing by the planning agency and to the prediction of air quality levels. (See Prediction Model section of this report.)

NASHVILLE METROPOLITAN AREA AIR QUALITY GOALS

With sufficient technical and scientific information concerning effects of various air pollutants and combinations of pollutants, it would be possible to establish standards of air quality that would be optimum for any community. As yet the level of technical and scientific endeavor is insufficient to reach this ideal; however, the Nashville studies and others provide sufficient information to allow the presentation of air quality goals related to sulfur dioxide, suspended particulates, soiling quality, and dustfall. These goals, as used here, are considered less rigid than legal standards, thus their values can be adjusted as found necessary. They provide for better understanding and community action concerning air quality and are the basis for establishing legal regulations applicable to emission of air pollutants from various sources.

Sulfur Dioxide Goal

A sulfur dioxide goal of 0.1 ppm for a 24-hour average, not to be exceeded on more than 1 percent of the days during any 100-day period, is proposed. This goal, based on the West and Gaeke method of analysis, should apply to any place where people live or where an undesirable effect could result from levels above the goal. The goal has been selected on the basis of specific information concerning health effects observed in Nashville and supplemented by expert opinion from the fields of health, agriculture, atmospheric chemistry, materials damage, and others. Some of the information relating to effects of sulfur dioxide are summarized in Table 29. The maximum short-term concentration on a day when the 24-hour average is 0.1 ppm would be expected to be above 0.3 ppm since the peak concentration for a 24-hour period is sometimes three (or more) times the 24-hour mean concentration. This is in the realm of conscious response by people since the taste threshold for sulfur dioxide is 0.3 ppm. [67] Such conscious response would occur, however, on only a few days of a year.

Table 29. REPORTED ATMOSPHERIC CONCENTRATIONS AND POSSIBLE RESPONSES TO SULFUR DIOXIDE AT VARIOUS LEVELS

Human response where applicable	Sulfur dioxide concentration, ppm	Reported effect
Subconscious	0.2	Dark adaptation threshold (Ref. 29). Damage to very sensitive plant life (Ref. 43).
Conscious	0.3	Taste threshold (Ref. 63).
	0.25-0.4[a]	Nashville. Adult asthma attack rate 3 times higher in high SO_2 area than in low SO_2 area (Ref. 56).
	0.4	7-hour exposure injures most sensitive plants (Ref. 44).
	0.5	New York smog episode, Nov. 1953, 200 excess deaths (Ref. 64).
	0.6	Odor threshold of sensitive persons (Ref. 65).
	0.7[b]	London smog episode, Dec. 1952. 4,000 excess deaths (Ref. 43).
Offensive	1	Guinea pig bronchoconstriction (Ref. 66).
	5	Bronchoconstriction in humans (Ref. 44).
Intolerable	10	Irritation and distress in humans (Ref. 44).

[a] Based on sulfation measurements and converted to Thomas Autometer 24-hour mean sulfur dioxide values reached or exceeded 1% of time by statistical methods in References 70 and 71 and values from Figure 22.

[b] Average concentration during episode.

Suspended Particulate Goal

The suggested goal for suspended particulate matter as measured by the Hi-Vol filter sampler is 200 micrograms per cubic meter, not to be exceeded on more than 1 percent of the days during any 100-day period. This applies to any point where land and air uses are such as to make an effect objectionable. The Nashville annual average of suspended particulate matter was 125 micrograms per cubic meter. This compares to an average of 101 micrograms per cubic meter in United States cities of similar size. The fall season in Nashville produces higher average values of 141 micrograms per cubic meter and maximum values of over 600 micrograms per cubic meter. Visibility, public opinion, high soiling indexes, and in particular the relatively high level of potential cancer-causing materials in Nashville particulates, all indicate that higher levels of suspended particulates exist than appear to be in the community's best interests. The suggested goal for suspended particulates is not as scientifically defensible as that for sulfur dioxide; however, consideration of all the factors involved and the steps that can be taken to reduce present levels indicate both its desirability and feasibility.

Soiling Index Goal

An air quality goal related to the soiling index of 4.5 Cohs per 1,000 lineal feet not to be exceeded over 1 percent of the time during any 3 months is proposed. This goal is based on winter season conditions, reduction of emissions similar to that indicated for particulate matter as measured by the Hi-Vol filter, and recognition of practical limitations indicated by the measurements at the semirural control stations in the summer season. It should apply to any place where people live or land uses are such as to make an effect objectionable. Compared with the New Jersey suggested air quality classification, a goal of 4.5 Cohs per 1,000 lineal feet seems high. This goal may not result in an adequate reduction in soiling effects or satisfactory visibility and must be considered subject to change if future measurements indicate modification to be desirable.

Figure 15 extended shows a winter season level of 13 Cohs per 1,000 lineal feet exceeded for 1 percent of the time, with an average of 2.3 Cohs. The proposed goal of 4.5 Cohs calls for a reduction of the average to 0.8 Coh, which would require a reduction in average emission levels of 65 percent.

To reach a soiling goal of 3.0 Cohs, not to be exceeded over 1 percent of the time, would require a reduction of 78 percent, giving an overall average of 0.50 Coh (Figure 15). This does not appear to be realistic, but would require reductions similar to those needed to achieve a total suspended particulate loading of 150 micrograms per cubic meter on not more than 1 percent of the days (Figure 45).

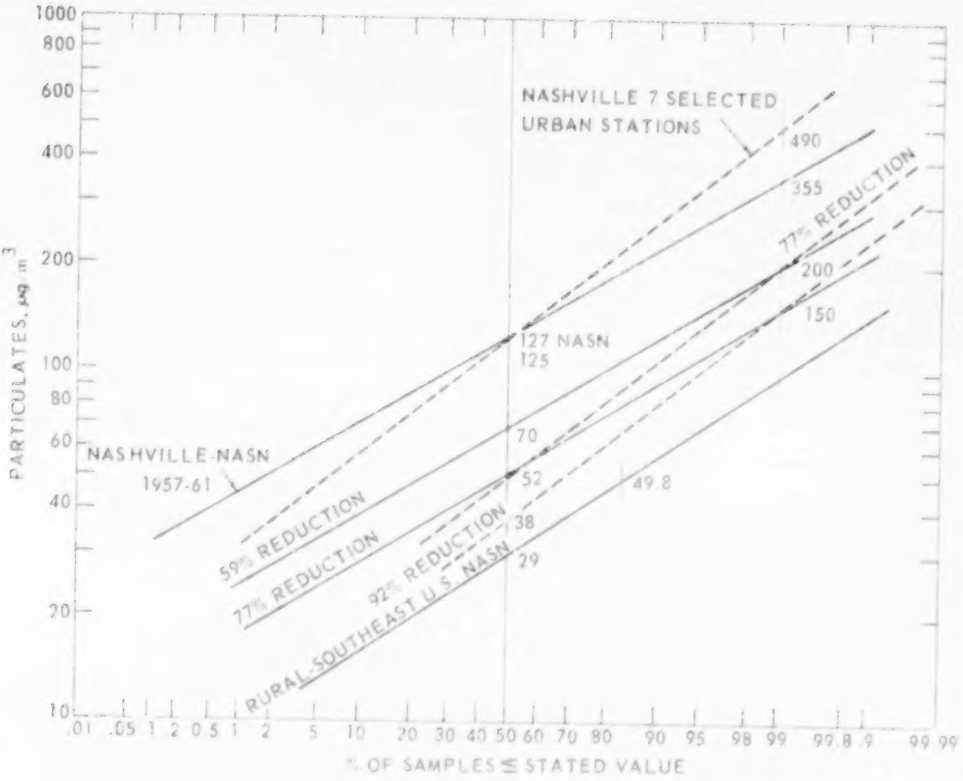

Figure 45. Frequency distribution of suspended particulates, 24-hour geometric means

In this case, as with other goals based on 1 percent of time occurrence, a reduction in peak concentration will result in reaching the goal without undertaking the total reduction indicated as being needed by average values.

Dustfall Goal

A dustfall goal of 10 tons per square mile per month, not to be exceeded by any yearly station average, is proposed. This is based on water-insoluble dustfall only. If the water-soluble portion of dustfall were included, the value would be 18 tons per square mile per month. These values include normal background dustfall. The dustfall measurements are explained in the Air Quality section of this report.

Since large particles tend to settle out of the air near their sources, a treatment of the data to indicate percent reduction of emissions throughout the community needed to reach the air quality goal is not very useful. The reductions indicated for particulate matter (total weight and soiling index) are expected to bring about the desired reduction in dustfall.

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SOURCE EMISSION REDUCTION TO MEET AIR QUALITY GOALS

Reduction of emissions at the source is the principal means applied to achieve improved air quality and to reach air quality goals. The three measures of particulates in the goals just discussed are interrelated; the reduction of one influences the level of others. Sulfur dioxide emission reduction might also result in a decrease in measured particulate pollution levels, depending on the measures employed to reduce sulfur dioxide emissions. Reductions in nitrogen oxides, oxidants and other pollutants generally will not be affected by emission control measures discussed in this report. Air pollution from natural sources, such as pollens and molds, smoke from forest and grass fires, mineral dust, particles from wind erosion, and fragments of eroded vegetation, likewise will be unaffected.

Method of Calculating Reduction Needed to Meet Goals

To translate air quality goals into action, a means is needed to determine the desired reduction in pollutant emissions. A practical solution to this problem consists of plotting the frequency distribution of pollution concentrations on log probability graph paper and from this determining the percent reduction needed to obtain a given air quality.[63] This calculation is accomplished graphically by drawing a line parallel to the measured pollution distribution line and intersecting the 1-percent-of-days abscissa at the desired concentration (Figure 46). The expected concentration can be determined from this line for any given percent of samples, sampling times, or time periods.

The source reduction may also be determined mathematically by using an equation developed by Dr. Ralph I. Larsen, using Los Angeles aerometric and meteorological data for the years 1955 through 1958.[63] These data were summarized on automatic data handling cards by means of an appropriate computer program. A second computer program was written to perform correlation and regression analysis for any two variables. This analysis provided the basis for determining the percent reduction needed to achieve a desired goal from the following equation:

$$\text{Percent of pollution removal} = 100 \left[1 - \frac{(\text{P.S.})}{(\text{F.S.})} \; \frac{(\text{D.C.})}{(m_g)\;(s_g)^t} \right]$$

where:

m_g = Existing 24-hour geometric mean concentration, ppm, $\mu g/m^3$, etc.

s_g = Standard geometric deviation

t = Number of standard deviations corresponding to the desired frequency of occurrence

= 2.33 on 1% of days

= 1.28 on 10% of days

P.S. = Present emission source strength, tons/day, lb/hr, etc.

F.S. = Estimated future emissions source strength, tons/day, lb/hr, etc.

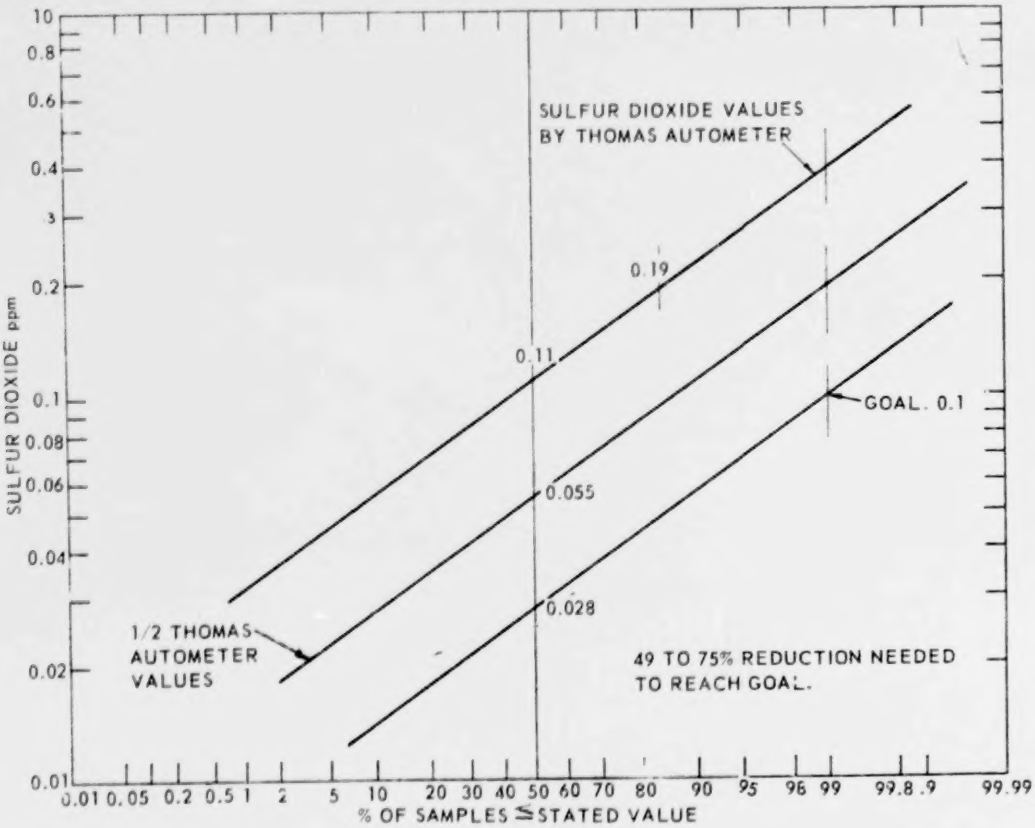

Figure 46. Sulfur dioxide frequency distribution, Thomas Autometer, January - June 1959.

D.C. = Desired pollution concentration, ppm, $\mu g/m^3$, etc., based on desired time interval.

These graphical and analytical methods can be applied to any primary pollutant for which the frequency distribution of air concentrations is known.

Sulfur Dioxide Reduction Required

The atmospheric sulfur dioxide concentration was measured with a continuous recording Thomas Autometer instrument during the period January through May 1959 at station 60 in Nashville. Since a frequency distribution is needed to calculate the percent reduction, these data were used. As previously discussed, however, in Nashville the TCM method, which is specific for sulfur dioxide, gave results that were approximately half of those of the Thomas Autometer. To allow for the implications of this difference, the Autometer data are handled as recorded and with a reduction to half-value. The resulting frequency distributions were plotted on log-probability paper (Figure 46). The percent reduction is determined graphically by drawing a line parallel to the plotted frequency distribution line intersecting the 1 percent of days abscissa at the 0.1-ppm point, the desired sulfur dioxide air quality goal. This line intersects the 50-percent-of-days abscissa at a concentration of 0.028 ppm; thus a general reduction of sulfur dioxide emissions of 75 percent is needed to achieve the desired goal of 0.10 ppm not to be exceeded on over 1 percent of the time.

The Thomas Autometer data gave a 24-hour geometric mean value of 0.11 ppm and standard geometric deviation of 1.73 ppm.

Using the desired 24-hour average concentration goal of 0.10 ppm or lower at any point, and assuming present and future source strength will remain constant, the percent reduction is determined as follows:

$$\begin{aligned}\text{Percent reduction} &= 100 \left[1 - \frac{0.10}{(0.11)\,(1.73)^{2.33}}\right]\\ &= 100 \left[1 - \frac{0.10}{0.395}\right]\\ &= 75\%\ \text{reduction.}\end{aligned}$$

This calculation agrees with the graphical determination of 75 percent reduction needed to achieve the same goal.

A 49 percent reduction in sulfur dioxide is needed to reach the sulfur dioxide goal if it is assumed that the Thomas Autometer readings are in fact double the true values for sulfur dioxide. This conclusion is reached by dividing the 24-hour geometric mean of 0.11 ppm by 2, plotting this frequency distribution on a graph (Figure 46), and finding that an overall reduction from 0.055 to 0.028 ppm is indicated. This is a 49 percent reduction. The true condition probably lies between the two values given.

Suspended Particulate Matter Reduction Required

The same method of calculation used for the sulfur dioxide reduction determinations can also be applied to suspended particulate matter levels. This would determine the gross pollutant emission reduction needed to achieve the desired air quality goal. In the case of particulate matter, there exists a portion of the overall concentration that arises from natural sources (wind entrainment, road dust, etc.). This background (natural) concentration is considered irreducible; therefore, it was not included in the percent reduction base (see Figure 45). Background is taken as that reported for nonurban air sampling stations in the Southeast United States by NASN from 1957 through 1961 (29 micrograms per cubic meter geometric mean and 1.69 standard geometric deviation) rather than 62 micrograms per cubic meter indicated by the four Nashville study control stations (Table 30). These control stations reflect urban influences since they are only 7 miles from the center of the city.

Table 30. SUSPENDED PARTICULATE CONCENTRATION AT FOUR CONTROL STATIONS AND SOUTHEAST UNITED STATES

Location	Concentration, $\mu g/m^3$	
	Geometric mean	Standard geometric deviation
Nashville control stations		
120	63	1.55
121	68	1.47
122	51	1.70
123	68	1.61
4 stations collectively	62	1.60
National Air Sampling Network, nonurban, Southeast region 1957-1961	29	1.69

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For those pollutants where the background contribution should be considered (especially particulates), the log probability plot method is preferable. The information from the plotted data is used to calculate the percent source reduction needed to achieve the desired level of air quality as follows:

$$\text{Percent of source reduction needed} = 100 \left[\frac{(A-C) - (B-C)}{A - C} \right]$$

where:

A = Existing concentration

B = Desired air quality goal concentration

C = Background concentration

Geometric mean concentrations, 99th percentile, or other values may be used in the calculations; care should be taken to relate the percent reduction required to the values used. In the Nashville calculations the NASN data from 1957 through 1961 and data from the seven selected stations from the 1958-59 study were used. NASN, which was established in 1953, gives a readily available record of suspended particulate matter concentrations at one location over a period of years and as such is used as an index for evaluating general trends. The location of this station on the City-County Building is classified by the NASN as a mixed-use area, residential, commercial, and industrial. Values obtained at this station are typical of those for a large part of the central area of Nashville. This was indicated by the 1958-59 study results, which showed that one station in this general location plus one control station yielded essentially the same average value as a network of seven stations.

The annual 24-hour geometric mean concentration for the seven selected urban stations used during the study was 125 micrograms per cubic meter with a standard geometric deviation of 1.825. Applying the graphical-mathematical method to the data from these seven stations, an average emission reduction of 73 percent is needed to obtain a reduction from the 490 micrograms per cubic meter measured on 1 percent of the days to the desired goal of 200 micrograms per cubic meter on not more than 1 percent of days (Figure 45). This is calculated as follows:

$$\text{Percent of pollution removal} = 100 \left[\frac{(490-94) - (200-94)}{490-94} \right]$$

$$= 73 \text{ percent.}$$

The percent reduction would be 77 percent if mean data were used in the calculation. This resulting difference is explained by the greater standard geometric deviation of the background data giving a greater relative concentration for 1 percent of days. A 92 percent reduction would be needed to achieve the more desirable residential goal of 150 micrograms per cubic meter not to be exceeded on more than 1 percent of days.

The annual 24-hour geometric mean concentration at this NASN station was 127 micrograms per cubic meter with a standard geometric deviation of 1.57. The graphical solution indicates that an emission reduction of 59 percent is needed to achieve the desired goal of 200 micrograms per cubic meter on not over 1 percent of the days (Figure 45). The average level would then be 70 micrograms per cubic meter. By comparison, a 77 percent reduction would be needed to achieve 150 micrograms per cubic meter on not more than 1 percent of days. This would result in an average level of 52 micrograms per cubic meter, only 23 above the background values found in nonurban areas.

The results from the seven stations show the effects of both cleaner and dirtier areas as compared to the single NASN station. The high values would be associated with industrial areas and the low values with residential areas. Since industrial areas can not reasonably be expected to have the same quality air as residential areas, it is appropriate to give more weight to the NASN data and apply the suggested goal to residential and commercial areas.

The temporal distribution of pollutants in the rural and urban areas appears to be markedly different. Data from NASN for 1957-1961 indicate that high values for the rural areas occur in the summer, and those for the urban areas occur in the winter; therefore, reduction of high values (those occurring on 1 percent of the days) in the urban areas would be accomplished with a somewhat lower percent reduction than Figure 45 tends to indicate.

APPROACHES TO REGULATING POLLUTANT EMISSIONS

The technical means are available to reduce air pollutant emissions to the extent necessary to reach the air quality goals described earlier. Particulate matter emissions can be reduced by installation of dust collectors on the exhaust of various fuel-burning and industrial-process operations. Equipment used and certain information about it are given in Table 31. In other cases, particulate matter emissions can be reduced by changing the kind or characteristics of fuel used, changing processes or process materials, changing process or fuel-burning equipment, enclosure of dusty operations, paving of roadways, and surface stabilization of material storage piles. The means to be used in a given situation requires specific study from the standpoint of efficiency of emission control, economics, and technical and practical feasibility.

Emission of sulfur dioxide from fuel-burning installations can be reduced by using fuel containing less sulfur. Lower sulfur fuels may

Table 31. APPROXIMATE CHARACTERISTICS OF DUST AND MIST COLLECTION EQUIPMENT[a]

Equipment type	Purchase cost[b], dollars/1,000 ft^3/min	Smallest particle collected,[c] μ	Pressure drop, in. H_2O	Power used,[d] kw/1,000 ft^3/min	Remarks
Settling chambers					
Simple	100	40	0.1-0.5	0.1	Large, low pressure drop, precleaner.
Multiple tray	200-600	10	0.1-0.5	0.1	Difficult to clean, warpage problem.
Inertial separators					
Baffle chamber	100	20	0.5-1.5	0.1-0.5	Power plants, rotary kilns, acid mists.
Orifice impaction	100-300	2	1-3	0.2-0.6	Acid mists.
Louver type	100-300	10	0.3-1	0.1-0.2	Flyash, abrasion problem.
Gas reversal	100	40	0.1-0.4	0.1	Precleaner.
Rotating impeller	200-600	5	-	0.5-2	Compact.
Cyclones					
Single	100-200	15	0.5-3	0.1-0.6	Simple, inexpensive, most widely used.
Multiple	300-600	5	2-10	0.5-2	Abrasion and plugging problems.
Filters					
Tubular	300-2000	< 0.1	2-6	0.5-1.5	High efficiency, temperature, and humidity limits.
Reverse jet	700-1200	< 0.1	2-6	0.7-1.5	More compact, constant flow.
Envelope	300-2000	< 0.1	2-6	0.5-1.5	Limited capacity, constant flow possible.
Electrical precipitators					
One-stage	600-3000	< 0.1	0.1-0.5	0.2-0.6	High efficiency, heavy duty, expensive.
Two-stage	200-600	< 0.1	0.1-0.3	0.2-0.4	Compact, air-conditioning service.
Scrubbers					
Spray tower	100-200	10	0.1-0.5	0.1-0.2	Common, low water use.
Jet	400-1000	2	-	2-10	Pressure gain, high-velocity liquid jet.
Venturi	400-1200	1	10-15	2-10	High-velocity gas stream.
Cyclonic	300-1000	5	2-8	0.6-2	Modified dry collector.
Inertial	400-1000	2	2-15	0.8-8	Abrasion problem.
Packed	300-600	5	0.5-10	0.6-2	Channeling problem.
Rotating impeller	400-1200	2	-	2-10	Abrasion problem.

[a] Taken from Reference 29.

[b] Steel construction, not installed, includes necessary auxiliaries, 1960 prices.

[c] With 90-95% efficiency by weight.

[d] Includes pressure loss, water pumping, electrical energy.

sometimes be obtained by changing the source (mine or oil field) from which fuel is obtained or by removing sulfur from the fuel by physical or chemical means. Changing from a fuel containing much sulfur to one containing little sulfur will substantially reduce sulfur dioxide emissions. Sulfur dioxide emissions from industrial processes can be reduced by providing close control of processes, changes in raw materials used, installation of absorbing equipment on exhaust stacks, or changes in operating procedures.

Control of smoke emissions from fuel-burning plants can be accomplished by use of good combustion equipment, by use of proper operating procedures, and by selection of fuels appropriate for use in a particular furnace. Prevention of smoke from hand-fired coal-burning plants is very difficult and can only be reliably controlled by installation of mechanical firing equipment.

Control of emission of substances that cause odors can be accomplished by use of scrubbers, adsorbers, and exhaust gas incinerators. Changes in materials, operating procedures, and process equipment may also find application to odor control problems.

As a means of regulating emission of pollutants to the atmosphere, a variety of requirements to be met by several classes of pollutant sources should be set forth in an ordinance, rule, or regulation. Those requirements considered necessary to provide Nashville with air in keeping with the air quality goals set forth earlier herein are given in the following sections.

Reduction of Smoke and Sulfur Dioxide from Use of Coal

Data from the pollutant emission inventory[11] show that 463,200 tons of coal per year was used in the Nashville area. Use of coal is responsible for about 85 percent of the total sulfur dioxide emissions and 33 percent of the particulate emissions on an annual basis (Table 14). Further consideration of the sources of atmospheric particulate matter indicates that the combustion of coal in all probability actually contributes more than 33 percent of the suspended particulate matter collected by Hi-Vol air samplers and strip filter paper samplers. This is true because a high proportion of the particles emitted from coal-burning plants are less than 10 microns in diameter and of low density.[68] Particles of 10 microns or less in diameter tend to remain suspended in air and are collected by the air samplers. In contrast, a relatively high proportion of the particulate matter emitted from sand and gravel handling industries (some 46 percent of the total particulate emissions) range from 10 to 1,000 microns in diameter. These larger particles tend to settle out of the air in a short time. Because of their rate of fall, they may be excluded from particulate sampler air intakes.

As a practical matter, burning high-volatile-content coal in hand-fired furnaces and stoves without causing emission of excessive smoke is not reasonably possible. Virtually all of the coal used in the Nashville area has a high-volatile-matter content (Table 6). No doubt much of the smoke pall over Nashville during the space-heating season is attributable to use of high volatile coal in hand-fired furnaces. Although no precise information is available, it is estimated that about 50,000 tons of high volatile coal is burned per year in residential hand-fired units. This is about 40 percent of the coal used for heating dwelling units. If smoke from hand-fired coal-burning sources could be controlled or eliminated, total smoke emissions could be reduced perhaps 50 to 75 percent. Use of coal of lower-volatile-matter content in hand-fired units might bring about some reduction in smoke emissions; however, no such coal is readily available at attractive prices, and the degree of smoke reduction would probably be inadequate in the long run.

Burning of coal is responsible for about 85 percent of the atmospheric sulfur dioxide in the Nashville area (Table 14). The data in Table 14 are annual averages. Since a considerable portion of the coal is used for space heating, the relative emission of sulfur dioxide from coal combustion would be even greater in the cold winter months. This peak seasonal use is even more important because of periods of atmospheric stability that occur primarily during the fall and early winter. The 28,879 dwelling units heated by use of coal consume about 4.5 tons of coal each per heating season, [11] amounting to 129,955 tons annually. These residential units used 28,529 tons, or 23 percent of the total coal consumed for yearly residential space heating during December 1958, a month with 886 degree-days. The net effect is shown in the seasonal increase of sulfur dioxide and soiling index (Figure 17). The use of coal by commercial and industrial establishments is about 333,000 tons per year. If this coal were used at a uniform rate throughout the year, average monthly use would be about 28,000 tons per month. Since a substantial part of this coal is used for space heating, maximum monthly use is probably about 1-1/2 times this average, or roughly 42,000 tons per month. Thus, during a cold winter month, use of coal for residential space heating is about 40 percent of the total.

The air quality goal of 0.1 ppm sulfur dioxide (24-hour average), not to be exceeded on more than 1 percent of the days, is about equivalent to a long-term average concentration of 0.03 ppm sulfur dioxide (average of a series of 24-hour measurements) (Figure 46). Figure 17 indicates that this goal was exceeded during the study only in the months of December and January, the 2 coldest months when use of fuels for space heating was at a maximum. This would indicate that the air quality goal could be achieved by reducing sulfur dioxide emissions during these 2 months (and desirably also in November and February, to allow for temperature variation from year to year.) (See also Figure 21).

The possibilities worthy of consideration for reducing smoke and sulfur dioxide from use of coal are as follows:

1. To reduce smoke emissions, eliminate use of coal in hand-fired units, and substitute another means of heating (i.e., natural gas, distillate oil, or electricity) or, less desirably, substitute stoker-fired units.

2. To reduce sulfur dioxide emissions, reduce the amount of coal used, and substitute another means of heating (i.e., natural gas, distillate oil, or electricity) or substitute lower-sulfur-content coal for presently used high-sulfur-content coal.

The use of coal for residential space and water heating and for cooking has been declining rapidly over the past 20 or more years. This is largely due to the convenience and cleanliness of other fuels. Use of coal requires manual feeding of fuel, removal of ashes, and periodic replenishment of the stock of fuel. There is no doubt that a home is cleaner if coal and ashes are not handled on the premises. Another factor in causing the decreased use has been the improved competitive cost situation of heating with natural gas and electricity as compared to coal. The factors tending to make use of coal undesirable are not quite so important or dominant in multiple-family dwellings heated with a single furnace. The past trend of decreased use of coal in domestic establishments is likely to continue no matter what regulatory steps are taken. Nevertheless, in view of the major reductions of sulfur dioxide and smoke emissions that can be made by eliminating the use of coal in hand-fired units and the reductions of sulfur dioxide (and some smoke) that can be made by reducing the total amount of coal burned during the space-heating season, it is considered appropriate to consider an ordinance or regulation to be adopted to accelerate these desirable trends and ensure widespread action. It is therefore recommended that use of coal in hand-fired furnaces and stoves of all sizes be prohibited. To provide for orderly compliance with this requirement, it would be proper to allow a reasonable time of 3 to 5 years for those persons involved to make the necessary changes. A schedule for progressive compliance based on geographic or other factors could be established to ensure that some portions of the necessary changes were made each year.

As a further means of reducing sulfur oxides, smoke, and ash emissions, it is recommended that no new coal-burning plants with a heat input of 1,000,000 Btu per hour or less be permitted and that existing coal-burning plants of these small sizes be gradually phased out of existence. Coal-burning plants having a heat input of 1,000,000 Btu per hour or less (e.g. serving a six-family apartment or a smaller building) are difficult to operate in an ash- and smoke-free manner and impossible to operate without emission of sulfur oxides. Installing equipment to reduce ash emissions is not economically feasible. Since such plants are small, they usually have short chimneys; therefore, the smoke, ash, and other pollutants emitted often reach neighboring homes in high concentrations. All things considered, operation of coal-fired plants in this size range is probably more expensive than use of other fuels. This requirement should not apply in parts of Davidson

County where natural gas is not available. In order to prevent economic hardship, compliance with this requirement could be made effective with respect to each specific unit as to the time it has been in service for perhaps 15 years.

The previous measures, if implemented, would bring about a reduction of sulfur dioxide emissions during the space-heating season of some 30 to 40 percent, not enough to accomplish air quality in keeping with the goal for sulfur dioxide. The recommended available means of achieving the necessary additional reduction would be (1) to establish 2 percent as the maximum allowable sulfur content of coal (or oil) used by commercial, industrial, and perhaps a few multiple-dwelling establishments needing rated capacities of more than a million Btu's per hour or (2) to substitute means of heating such as natural gas or electricity during the period November through February.

Most coal presently used in the Nashville area comes from Western Kentucky. It has a sulfur content of 3.0 to 4.4 percent with an average of probably 3.5 percent. Eastern Kentucky coal and Tennessee coal have a sulfur content ranging from 0.5 to 1.0 percent (Table 6). To substitute these lower sulfur coals for the presently used higher sulfur coal would bring about a reduction of sulfur dioxide emissions of substantial proportions; however, these lower sulfur coals would cost more. To minimize this additional cost, requirement for the use of these coals could be limited to the critical period of November through February. An alternative would be to switch to natural gas or distillate fuel oil during this period, provided the available combustion equipment in specific cases would be adaptable to such action. Another possible alternative would be to remove some of the sulfur from presently used Western Kentucky coal by one of several coal cleaning methods. Because of the characteristics of the sulfur-bearing constitutent of this particular kind of coal that might be removable (the pyrites) by available methods, it is unlikely that the sulfur in the Western Kentucky coal could be reduced substantially at an acceptable cost or even at any cost.[69] Another problem would be that in sulfur removal processes that effect the elimination of major amounts of sulfur, the coal is crushed into very small sizes. This renders the coal usable only in furnaces designed to burn coal in suspension.

Reduction of Ash Emissions from Fuel Combustion

The previously suggested measures will provide for reduction of smoke emissions, but will not necessarily cause a decrease in flyash emissions. In a practical sense, flyash is controlled by using flyash collectors, reducing firing rates, or using low-ash-content fuel. In terms of regulations, an ordinance should provide that flyash emissions should not exceed the amounts indicated by Figure 47, for the size of furnace involved. Units with a heat input of less than 1,000,000 Btu per hour would be exempted from this requirement. Since some installations may have already been equipped with flyash collectors in

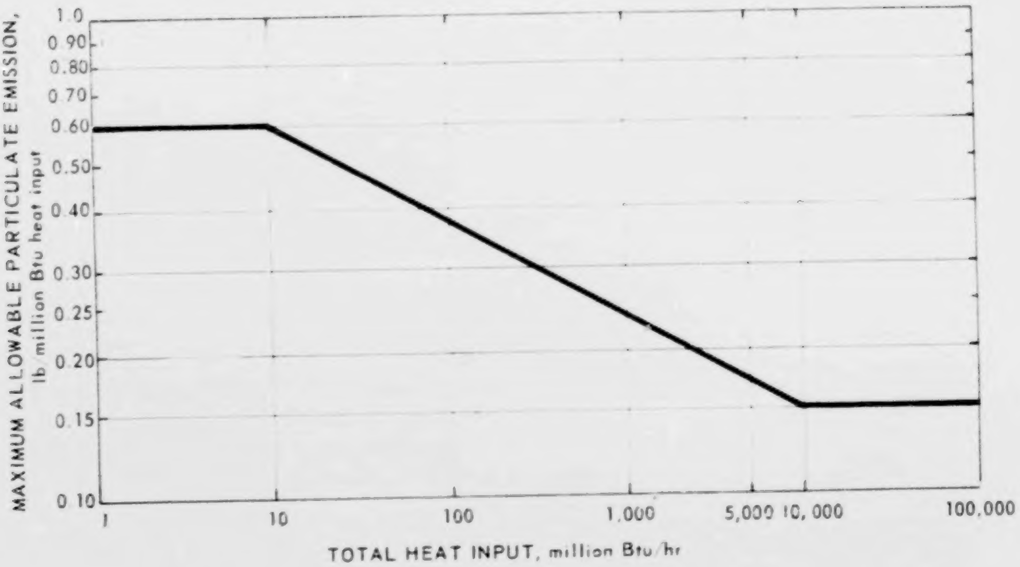

Figure 47. Maximum permissible emission of particulate matter from indirect-heating, fuel-burning installations in Nashville Metropolitan Area.

order to comply with previously existing ordinances, it would be appropriate to exempt such units from the new limitations for a period of time, perhaps until the unit has been in service 15 years.

Control of Visible Pollutant Emissions

Inefficient combustion of fuels (coal, oil, wood), refuse, and certain industrial process wastes causes emission of excessive amounts of particulate matter. These excessive emissions usually result in a visible plume from the exhaust stack of the basic combustion or process equipment. The particulate matter contributes to the total loading of particulates in the atmosphere. To minimize or eliminate these visible plumes would surely result in a reduction in the particulate loading in the atmosphere, but available data do not permit estimating the amount of decrease. Emission of excessive smoke has long been regulated by enforcement of ordinances prohibiting emissions darker than a stated shade of the Ringelmann Chart. In recent years, some cities have regulated emission of particulate matter other than smoke by enforcement of ordinances prohibiting emission of particulate matter of such opacity (near the stack exit) as to obscure an observer's view to a degree equal to or greater than does smoke of a stated Ringelmann shade. Even though the Ringelmann Chart method of quantitating particulate emissions is less precise than desirable, it is, when used by trained personnel in a prudent manner, an effective, useful, and economical means of finding and bringing about control of excessive emissions of smoke and other particulate matter. It is, therefore, recommended that an ordinance or regulation be adopted to prohibit emission of smoke as dark or darker than No. 1 on the Ringelmann Chart and emission of other particulate matter of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke as dark or darker than Ringelmann No. 1. This ordinance should apply to all establishments, including residential. Certain exemptions that permit emission of visible emissions in excess of those stated during brief times when a fire is being built or equipment is being cleaned or is out of order, etc., should be provided. Granting a variance to certain establishments with regard to the opacity limits for particulate emissions other than smoke may also be advisable. This would be done best on an individual case basis, after a public hearing.

Control of Pollution from Burning of Refuse

To control air pollution due to burning of combustible wastes (refuse), a primary requirement should be that no open burning be done. Burning of refuse in open fires or in any device other than a properly designed incinerator should not be allowed. To impose this requirement in the Nashville area would reduce particulate emissions by about 10 percent. In addition, hydrocarbon emissions would be reduced by around 30 percent and some local smoke and odor nuisances would be eliminated.

Refuse burning incinerators, unless properly designed and operated, can cause smoke, odors, and excessive particulate matter emissions. It is, therefore, recommended that all newly constructed incinerators be of multiple-chamber design, or of an equally effective design for purposes of air pollution control. Additionally, all newly constructed incinerators should comply with particulate matter emission limits as follows: from installations burning less than 200 pounds of refuse per hour, not more than 0.3 grain per standard cubic foot of flue gas; from installations burning 200 or more pounds of refuse per hour, not more than 0.2 grain per standard cubic foot of flue gas. (Both flue gas particulate emission values are as corrected to 12 percent carbon dioxide, not counting carbon dioxide formed by combustion of auxiliary liquid or gaseous fuel.) Existing incinerators that are not of multiple-chamber design and those that do not meet the recommended particulate matter emission limits should be replaced or brought into compliance on a specific schedule over a period of perhaps 5 years. The schedule could be on a geographic basis with those located in the central part of the city complying in 1 year, those in another zone in 2 years, and so on.

Control of Particulate Emissions from Industrial Processes

Control of particulate emissions from industrial processes is not a new concept to industrial management. Many industrial establishments have long recognized the necessity of controlling air pollution as a means of maintaining a good public image. In the role of a good neighbor, some companies have applied control technology to avoid local point-source problems. In some cases, an entire industry has developed and adopted the control technology necessary. A recent survey made among 175 leading industrial firms in the United States indicates that over a 5-year period the 69 percent that responded would make expenditures for air pollution control ranging from $1,700 to $20,000,000 each. Only 5 percent reported no expenditures.66 Because of the wide variation in process conditions, meteorological conditions, and necessities for control measures that exist from place to place, it is rare that a direct transfer of equipment or processes can be made from one installation to another in the application of control technology. Thus, each case must be considered individually, and the many facets involved must be evaluated carefully. The main facet is probably that of an emission limit or air quality goal. The cost of control equipment varies considerably and is dependent upon size of operation, temperature, effluent loading, and many other factors. Table 31 gives some approximate characteristics, including cost of dust and mist collection equipment.

To bring about control of particulate matter emissions from industrial processes in the Nashville area, it is recommended that a law or regulation limiting emissions to various amounts (in pounds per hour) for various process weights be adopted. Recommended values are given in Table 32. These values are the same as those used in California by the San Francisco Bay Area and similar to those used in some other cities. Essentially, these limitations require a reduction of emissions of about 80 percent for small operations and 90 percent or more for large operations. Enforcement of these suggested regulations in Nashville should provide the desired improvement in general air quality, prevent local nuisances, and still permit industrial operations to continue and expand.

Control of Odor Problems

A common complaint of citizens of the Nashville area concerns presence of odors. The survey made of public awareness of air pollution indicated that 26 percent of the people interviewed were bothered by odors. These odors arise from a wide variety of sources and are caused by an extremely large number of chemical compounds and mixtures of compounds. Pollutant measurement technology has not yet advanced to the stage where these odor-causing compounds can be measured in a convenient way nor are there data upon which to base an assessment of the physiological significance of most of these materials at concentrations experienced in the ambient air. For these reasons, emission regulations cannot be written, in most cases, in terms of specific quantities of emissions of particular pollutants. Desired atmospheric quality with respect to human olfactory response

Table 32. RECOMMENDED PARTICULATE EMISSION LIMITATIONS APPLICABLE TO INDUSTRIAL PROCESSING OPERATIONS IN NASHVILLE METROPOLITAN AREA

Process weight,[a] lb/hr	Allowable emission,[b] lb/hr	Process weight,[a] lb/hr	Allowable emission,[b] lb/hr	Process weight,[a] lb/hr	Allowable emission,[b] lb/hr
100	0.55	6,000	8.56	70,000	41.3
200	0.88	7,000	9.49	80,000	42.5
400	1.40	8,000	10.4	90,000	43.6
600	1.83	9,000	11.2	100,000	44.6
800	2.22	10,000	12.0	120,000	46.3
1,000	2.58	12,000	13.6	140,000	47.8
1,500	3.38	16,000	16.5	160,000	49.0
2,000	4.10	18,000	17.9	200,000	51.2
2,500	4.76	20,000	19.2	1,000,000	69.0
3,000	5.38	30,000	25.2	2,000,000	77.6
3,500	5.96	40,000	30.5	6,000,000	92.7
4,000	6.52	50,000	35.4		
5,000	7.58	60,000	40.0		

[a] Process weight is defined as the total weight of all materials introduced into an operation, including solid fuels, but excluding liquids and gases used as fuel and air used for purposes of combustion.

[b] Interpolation of the data in this table for process weight rates up to 60,000 lb/hr may be accomplished by use of the equation $E = 4.10 P^{0.67}$, and interpolation and extrapolation of the data for process weight rates in excess of 60,000 lb/hr may be accomplished by use of the equation $E = 55.0 P^{0.11} - 40$ where E = rate of emission in lb/hr and P = process weight in tons/hr.

to odorous pollutants can, however, be described, and a number of zoning laws do embody air pollution performance standards for various classes of industrial land use. A suitable regulation for the Nashville Metropolitan Area would prohibit emission of odorous materials in amounts detectable by the sense of smell by normal human beings in the ambient air in areas used for residential, recreational, educational, or similar purposes. In commercial areas, the need for odor-free air may not be considered so essential so that the presence of mild concentrations could be permitted. The regulation could prohibit emission of odorous materials in amounts detectable in commercial areas when the odorant-bearing air is diluted with four or more volumes of odor-free air. Requirements for air quality may be even less restrictive in industrial areas. Thus, the regulation could prohibit emission of odorous materials in such amounts as to cause a detectable odor in industrial areas when the air bearing the emitted odorant is diluted with 12 or more volumes of odor-free air.

Necessary observations of odor can be made by panels of three or more people. The prescribed dilutions can be prepared by use of a simple "Scentometer" or by use of glass syringes.[17] Field procedures for determining the source of odors in an area have been described in the same reference.

Control of Wind-Blown Surface Dust

Some local dust nuisances are caused by handling or storage of materials that may become wind-borne. Unpaved roadways and parking lots may also cause such troubles. An ordinance or regulation is recommended to prevent this type of nuisance and help meet the air quality goal for dustfall rates.

TRANSPORT OF AIR POLLUTANTS - METEOROLOGY

Sufficient meteorological information is contained in this report for the initiation of an air resource management program. By using standard diffusion formulas, estimates of the effects of planned new sources should be evaluated to determine their impact on air quality levels and, consequently, on air quality goals.

As resources become available to the air resource management program, further use of meteorology should be made. The following are some uses:

1. Predict days with high air pollution potential. This would supplement the Public Health Service - Division of Air Pollution program and relate specifically to the needs and conditions of Nashville.
2. Utilize meteorological and air pollution emission data to predict probable air quality levels by means of mathematical diffusion models and automatic data processing.

PLANNING AND ZONING BASED ON AIR QUALITY GOALS

To a considerable extent, in present-day metropolitan areas, community decisions center around the planning process, with resulting action reflected in land-use zoning and performance-type ordinances, and individual guidance based on the comprehensive plan in its several parts. In general, air pollution has not been seriously considered in these decisions. This is not surprising because of the lack of technical information concerning air pollution; however, the technical information is becoming available and needs to have a suitable organizational pattern to allow its expression. Any air resource management program established in the Nashville Metropolitan Area should have well-defined responsibilities and coordinating linkages between program elements to be able to operate most effectively.

IMPLEMENTATION OF CONTROL PROGRAM

No matter how extensive or precise may be the studies of air pollutant emissions, concentrations, and effects, they will all be for naught unless an aggressive program is instituted to ensure that the actions necessary to protect and improve the air resource are put into effect. Results of the various studies must be translated into specific regulations requiring that certain actions and practices be followed. Such regulations provide the rules under which both private parties and the regulatory agency are to operate. While it is true that many parties will voluntarily do those things necessary to preserve the air resource, it is wise to have guidelines for them to follow. There are unfortunately, a few parties who, in the community's best interest, must be compelled by legal action to conduct their activities in a manner that will not cause detriment to the community.

The implementation phase of an air resource management program involves the formulation of specific regulations setting out guidelines for allowable emissions, operating practices, land- and air-use patterns, securing of permits to build or operate facilities, etc. Of course, after formulation, the regulations must be given legal status by incorporation into an ordinance or by formal adoption as may be prescribed by law.

After the regulations are in effect, the responsible governmental agencies must take action to foster voluntary compliance and to compel compliance in those few cases wherein voluntary action is not forthcoming. This involves locating sources of pollution, determining their performance as compared to that required, reviewing all pertinent facets of the particular case, and negotiating specific plans and aggreements to bring about compliance. Then, as time proceeds, the agreed-upon plan must be followed; and if it is not, appropriate action must be taken to compel compliance with the regulations. Noncompliance to the extent that results in legal action does, in fact, occur in a very small percentage of the cases, but those few cases require skillful and tactful handling.

Another vital aspect of the implementation aspect of the air resource management program relates to public information. If the people and their elected representatives are to be expected to support desirable regulations and appropriations, they must be provided with information on which to base their opinions. If the public and certain segments of the public are to be expected to do those things required by air pollution regulations, they must be informed of them and advised as to the actions they are supposed to take.

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APPENDICES

APPENDIX A
Nashville and Davidson County
Inventory of Air Contaminant Emissions
Commercial and Industrial Sources

Firm Name: ____________________

Address: ____________________

Plant representative to be contacted
on air pollution matters: ____________________

Normal operating sched: ___hr per day ___days per year. Total number of employees ______

Principal materials processed or used (types and amounts per day): ____________________

____

____

____

*PROCESS EMISSIONS

Operations which are exhausted or release contaminants to outside air[1]	Materials processed and used at operation[2]	Quantity of exhaust (cfm)	Control equipment (if any)[3]	Dust, Fume, Gas, etc., exhausted		Basis of estimate[6]
				Type[4]	Quantity[5]	

USE BACK OF THIS SHEET IF NECESSARY

*EXAMPLES

1. Casting cleaning, spray painting, degreasing, iron-melting cupola, etc.
2. Ten tons per day iron castings cleaned, 10 gal. per day solvent used, 2,000 bbl. per day cement produced.
3. Baghouse, electrostatic precipitator, cyclone, settling chamber, wet scrubber, etc.
4. Iron oxide and silica dusts, trichlorethylene, formaldehyde, SO_2, HCW, etc.
5. Pounds per day, tons per month, or other convenient units, if known.
6. Assumption, material balance, tests by plant personnel or equipment manufacturer, etc.

NOTE: Any supplemental material or data considered pertinent (as reports, summaries, test results, maps and flow diagrams) may be attached and would be appreciated. Attach additional report sheet, as necessary.

FUEL COMBUSTION EMISSIONS

Is the firm the only occupant of the factory building in which it is located? (Yes, No)

If the answer to either of the above questions is Yes, please complete the FUEL CONSUMPTION DATA BELOW.

If the answer to the above questions is No, please indicate from whom the FUEL CONSUMPTION DATA may be obtained.

FUEL CONSUMPTION DATA

Fuel[1]	Type[2]	Amount[3]	Percent sulfur[4] (if known)

1. Coal, coke, fuel oil, gas, electricity, etc.
2. Examples: West Kentucky bituminous, No. 5 fuel oil, natural gas.
3. Examples: Tons per year, gallons per day, cubic feet per month, or other convenient units.

TRASH AND WASTES OPERATION COMBUSTION

Types and amounts of waste materials burned (e.g., 10 cu. ft. per day of paper, 3 bu. per day of sawdust and wood scraps, 2 tons mixed refuse per month etc.: ____________________

____

Method of burning (e.g., open dump, incinerator, salvage-process burner, etc.): ________

____

SALVAGE OPERATION COMBUSTION

No. of automobiles burned, lbs. of insulated wire burned, etc.: ____________________

____

Method of burning (e.g., open dump, incinerator, salvage-process burner, etc.) ________

____

Date ______________________ Reported by: ______________________

APPENDIX B
Nashville Community Air Pollution Study
Aerometric Station Network

Station Type	Code	Actual Location of Equipment
I	1	Telephone pole, east side Centennial Blvd. (Ford access road) 100 feet north of Women's Old Pen. Road
I	2	Marshall Avenue and Spencer Avenue. Utility pole across from last house on Spencer Avenue
I	3	Utility pole by Prison Guard House No. 7. Prison wall, northwest corner
II	4	Utility pole on Centennial Blvd. across from Ingram Oil and Refining Co.
I	5	Utility pole in front of 6005 Robertson (south side of street)
II	6	Utility pole near 120 Oceola
I	7	Utility pole in front of 4219 Hydes Ferry Pike
I	8	Utility pole across from 1501 East Stewart Lane
I	9	Davidson County Hospital (Asylum), second telephone pole from entrance on west side of Hospital Drive
I	10	Utility pole at 55th and California, northeast corner
I	11	Utility pole near 53rd and Elkins, 100 feet east of southwest corner
I	12	Utility pole in front of 5413 Knob Road, south side near Oakmont Circle
I	13	Utility pole near West End Avenue and White Bridge Road, rear of Esso Service Station off White Bridge Road
I	14	Utility pole on Belle Meade Blvd., 300 feet north of Honeywood, center island

Station Type	Code	Actual Location of Equipment
II	15	Utility pole on north side of Meadow View Road, first pole north of West Hamilton Road
I	16	Third utility pole northwest of Bratton on Hydes Ferry Pike across from 3701, south side of road
II	17	Utility pole opposite 3006 Hydes Ferry Road
I	18	Utility pole nearest river on west side of 39th Avenue, north of Centennial Blvd.
III A	19	Utility pole at 44th and Michigan, northwest corner
I	20	Utility pole midway between Wyoming and Idaho on east side of 42nd Avenue
II	21	Utility pole west side of Cherokee at Valley Road
I	22	Utility pole at Woodmont Circle and Clearview Drive, northwest corner
II	23	Utility pole on Sneed Road, across road from 4018 Sneed Road
I	24	First utility pole west of Tucker Road on north side of West Hamilton Ave.
I	25	Utility pole in front of 2310 Alpine, off West Trinity Lane, southeast side of Alpine
I	26	Second utility pole west of 2815 Clarksville Pike on south side of pike
I	27	Utility pole near front of 1605 Shrader Lane
I	28	Utility pole in front of 3107 Albion St.
I	29	Utility pole on Park Avenue at rear yard of 327 33rd Avenue, North
I	30	Utility pole on south side of Murphy Road, 100 feet west of North Park Circle
I	31	Utility pole on east side of Bowling Avenue at Brighton Road

Station Type	Code	Actual Location of Equipment
I	32	Utility pole on Cross Creek Road, south of Valley Brook, L. E. Matthew's yard
I	33	Utility pole at Castleman and Stammer, 4212 Stammer Place
II	34	Fifth utility pole west of Whites Creek Pike on north side of Moorman's Arm Road
I	35	Utility pole in front of 2704 Old Buena Vista Road
II	36	Utility pole with transformer at Gasser Airport, 300 feet south of hangar (clear with Airport - M. Gasser)
I	37	Utility pole 16th and Clay, southeast corner
I	38	Utility pole in front of 1824 Scovel St.
I	39	South side of Clifton Avenue at street light pole in front of Rock City Mill
II	40	Utility pole in front of 117 29th Ave., southwest side of 29th Ave.
I	41	Essex Place, 2508 - utility pole on north side
I	42	White Oak Drive, 2816 - last utility pole on east side
II	43	Richard Jones Road, utility pole north side, sixth utility pole east of Hillsboro Pike
I	44	East side of Lone Oak Road, first utility pole south of Randolph Place
I	45	Utility pole on east side of Whites Creek Pike at Francis Street
I	46	First utility pole west of Enloe on north side of Young's Lane
I	47	Utility pole 3rd and Clay, in front of 2000 3rd Avenue, North
III A+M	48	Nashville Housing Authority, first utility pole north of Taylor on Delta

Station Type	Code	Actual Location of Equipment
I	49	Utility pole at southwest corner 14th and Clinton
I	50	Utility pole 18th and Broadway, northeast corner (new pole)
I	51	18th and Capers, utility pole at northwest corner (or second utility pole north of corner on 18th)
III A+M	52	Utility pole in back of and across alley, 1800 Linden (shelter will be in back yard)
I	53	Utility pole in front of 1404 Woodmont
I	54	Utility pole across street from 1120 Duncanwood Drive, east side of Duncanwood Drive
I	55	Utility pole at mailbox at west side at 2909 Brick Church Pike
III A	56	Avondale Circle, utility pole vacant lot at 1221
I	57	Utility pole near 1341 Whites Creek Pike on east side of pike near White Front Market
II	58	First utility pole north of Van Buren on Burns (back of packing company)
I	59	Utility pole on 4th Avenue, North. First pole south of Harrison
III A	60	Utility pole at 9th and McGavock, northeast corner in parking lot. Thomas Autometer location
I	61	Utility pole across street from 1109 Archer, north side of street
II	62	Utility pole on west side of Elliott across from 1908 Elliott
I	63	Utility pole on south side of Kirkwood, just west of Vaulx Lane
II	64	3622 Wilbur Place, high utility pole corner of yard
I	65	Utility pole across street from 801 Crestwood, inside corner of fence

Station Type	Code	Actual Location of Equipment
I	66	Utility pole on south side of Lemuel just east of Hart, west of Dickerson Pike
I	67	Dickerson Pike, utility pole back of Howard Johnson's, by school drive
I	68	Utility pole on northwest corner of Evanston and Stockell
I	69	Street light utility pole east side of Meridian across from 302 Meridian
I	70	Utility pole northeast corner 2nd and Shelby. Front of Tallman Co.
I	71	Utility pole north side Lindsley at First and Lindsley, by entrance to Children's Museum
I	72	Utility pole just north of 1500 Martin St., on east side of Martin
I	73	Utility pole on south side of Craighead about 800 feet west of Bransford
I	74	Utility pole 200 feet west of West Iris Drive on north side of Thompson Lane (steel tower nearby)
I	75	Use A. T. & T. pole on east side of Franklin Pike near Norwood
II	76	Utility pole north side of Hart Street in front of 207 Hart, east of Dickerson Road
I	77	Utility pole in front of 2207 Jones Avenue, east side of Jones
II	78	Utility pole on north side of Blueridge between Rosedale and Montgomery, across from 806 Blueridge
I	79	Utility pole on west side of Myrtle, across from 703 Myrtle, north of Mansfield
II	80	South side of Shelby Avenue, light pole in front of 914-916 Shelby Avenue
I	81	6th and Davidson, northeast corner stub pole

Station Type	Code	Actual Location of Equipment
III A+M	82	Utility pole south side Hart Street in field of Trevecca College
I	83	Utility pole near front of 339 Woodycrest
II	84	Utility pole in alley behind 2503 Winford (south of Newsome)
II	85	East side of Sidco, south of Fontana, pole No. 10644-44
I	86	Utility pole east side of Sidco Drive, one pole north of Howell and Sidco intersection
I	87	Utility pole south side Ben Allen Road at Hutson Avenue
I	88	North side of Dozier - utility pole in front of 1033 Dozier Place
I	89	Utility pole in front of 1314 Greenwood, northwest corner of 14th and Greenwood
III A+M	90	16th and Forrest, utility pole southwest corner by 1520 Forrest and shelter house in back yard.
I	91	Utility pole at 16th and Electric Avenue in front of 1505 Electric (northwest corner)
I	92	Utility pole on west side of Rucker across from 302 Rucker
I	93	Utility pole Foster Avenue, east side 300 feet north of railroad
I	94	First utility pole north of Lyle on west side of Foster
I	95	Utility pole at dead end of St. Edwards (north of Thompson Lane)
I	96	Utility pole east side of Nolensville Road at High Street by 3312 Nolensville Road
II	97	Utility pole rear of 1141 Greenfield on west side of Katherine

Station Type	Station Code	Actual Location of Equipment
I	98	2126 Burns Street - utility pole at southwest corner of Burns and Ann Street
I	99	Utility pole southwest corner of Tillman Lane and Skyview Drive, in front of 212 Tillman Lane
I	100	Utility pole just north of Shelby Park about 100 feet north of RR underpass on west side of Riverside Drive
II	101	Near City Pumping Station north of Lebanon Road
I	102	Utility pole on Elm Hill Road at east end of Greenwood Cemetery by T.V.A. Power Maintenance Bldg.
II	103	North side of Hill Avenue, first utility pole west of Crutchfield Avenue
I	104	Utility pole 108 Dodge Drive, east side of Dodge
II	105	Next to last utility pole east side of Mavert Drive, dead end.
I	106	Utility pole in front of 2200 Ridgecrest on west side of Ridgecrest
I	107	Utility pole side of 2017 McKennel Avenue (east side of McKennel)
I	108	Utility pole on east side of Brittany Drive in front of 2612 Brittany Drive
I	109	About 800 feet west of northeast bend of Pumping Station Road. Utility pole at white stone front gate of H. E. Huffer
I	110	Utility pole Lebanon Pike south side between 1727 Lebanon Pike and Phillips Service Station
I	111	Utility pole in front of Baltz Brothers on south side of Elm Hill
I	112	Telephone pole on southeast corner of Rowwood and Longdale

Station			
Type	Code	Actual Location of Equipment	
I	113	Utility pole, dead end of Carlyle Place, 815 Carlyle Place	
I	114	Utility pole in front of 3910 Moss Rose Drive, east side of Moss Rose Drive	
II	115	Utility pole in front of 2710 Traughber Drive, south side of Traughber Drive	
II	116	Utility pole, southwest corner of Dearborn and Graeme Drive. Utility pole by driveway of 2138 Dearborn	
I	117	Utility pole near 128 Quinn Circle, southeast corner of intersection	
II	118	Utility pole on southeast side of Elm Hill by 2003 Elm Hill	
I	119	Utility pole east side of Connolly Drive in front of 894 Connolly Drive	
		Planned Location	Actual Location of Equipment
III	120	8 miles north	Utility pole No. 108 on east side of Brick Church Pike across from A. H. Cofer's house
III	121	8 miles south	West side of Old Franklin Road south of Old Hickory Blvd.
III	122	8 miles west	Utility pole No. 50-1/2, west side of Old Hickory Blvd. on west side of Cumberland River across Clees Ferry. Robert Buchanan's property
III	123	8 miles east	Utility pole on east side of Templewood at rear of 3122 Cloverwood Drive, property of H. F. Huffman, Donelson

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